NEW BIOLOGY

SMALLWOOD-REVELEY-BAILEY

Floyd
Ida

Floyd Crumpton

F E C.
L E B.

Floyd E. Compton
Sophomore Class '30

Floyd Eugene Compton
O. C.

"Salesmen Sam"

Mr Floyd Compton
Gold Hill Oregon

Floyd Compton

Courtesy Dr. George S. Britten.

REDHEADED WOODPECKER.

This photograph shows how the tail is used as a brace and how the toes are opposite so as to grip the bark of the tree. These are adaptations not seen in the house sparrow, for example. Do you see any other adaptation?

NEW BIOLOGY

BY

W. M. SMALLWOOD
SYRACUSE UNIVERSITY

IDA L. REVELEY
WELLS COLLEGE

GUY A. BAILEY
GENESEO STATE NORMAL SCHOOL

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FAO

PREFACE

THE New Biology offers a unit course dealing with the fundamental functions of living things. But, owing to the fact that different animals and plants may be used equally well in a study of these processes, we offer a wider selection than the minimum requirements.

The forms of life are so numerous and their interrelations so complex that only the more general facts are presented. Such a plan, however, gives an insight into the way that organisms live and the dependence of living things on the physical world. Some of these relations are modified by man as he uses them to serve his own ends.

We are coming to realize more and more that it is what an organism does that is important rather than the details of its structure, and this is the reason that we have departed somewhat from the older type study which has characterized earlier texts on biology.

Biology will take its recognized place as a valuable subject in training only when teachers require accuracy of observation and the recording of these observed facts in suitable note-books. It is possible to learn much about our own lives from the study of animals and plants, but trustworthy conclusions can be formulated only from reliable observations. We have suggested a method of study in the laboratory problems to train the student in accuracy of observing and recording.

All the remarkable progress in biological information has come through the painstaking observations of many scientists, who by their contributions have made the world a better place to live in. But in our zeal to apply these

brilliant discoveries to human welfare, we must not overlook the beauty of biology; and, as we attempt to understand life, let us not miss the delight that comes from simply knowing animals and plants in their homes. The first spring flower and the first immigrant bird herald the coming of spring. These in turn are followed by so many living things that every excursion to parks and woods throughout the summer and fall furnishes one with a most varied program of entertainment. Even the winter supplies many opportunities for the study of animals and plants that have now become our friends. One is richer and happier who has such a storehouse of pictures to enjoy when his duties do not permit him to wander a-field.

It is a pleasure to express our appreciation to the several high school teachers who have given us practical assistance by their friendly criticisms. We have drawn freely from the works of the numerous specialists in the many fields of biology whose contributions have made possible this book. Dr. Carlton F. Potter, Dr. David Gillette, and Dr. Walter Street have assisted the authors in showing the close connection between biology and our own bodies. The United States Department of Agriculture, The National Museum, The American Museum of Natural History, Nature Magazine, and many personal friends have furnished us with illustrations that add much to the value of this book.

W. M. S.
I. L. R.
G. A. B.

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B. G. Smith, Ypsilanti, Mich., 86.
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NEW BIOLOGY

PART I

THE IDEA OF BIOLOGY

CHAPTER I

THE LIFE OF THE APPLE TREE

As the twig is bent, the tree's inclined.
— POPE

1. A Study of Living Things. — Biology is the study of living things — plants and animals. In our study we are going to see: (1) how these things live; (2) what their relations are to one another; (3) how they depend on the physical world about them; and (4) man's power to control them.

But before we take up this regular work, we can illustrate much that we wish to know, by studying the life of something we are all familiar with, for instance, an apple tree.

2. The Seed and the Seed-leaves. — When the seed of an apple sprouts, a tiny plant comes through the ground bearing two green seed-leaves. There is a little stem that joins the leaves and there are small roots that reach down into the ground. In a few days two more leaves appear. These are thinner and of a deeper green color than the seed-leaves.

3. The Plant and the Soil. — The little seed that we began with is now a well-developed plant. It has all the parts that a small plant needs. The roots take up food in the form of solutions, that is, water in which parts of the soil are dis-

solved. These roots must grow in soil. They cannot live if they are exposed to the sunlight. And the soil must be of the right kind if the plant is to grow well. Then too, there must be considerable water in the soil to dissolve parts of the soil for the root to absorb.

As the plant grows older, it sends out a greater number of roots. These branch and subdivide and almost fill the soil

FIGURE 1. — THE APPLE TREE IN BLOSSOM.

with their tiny rootlets. They take up about as much space in the ground as the branches do in the air. If we could take a tree from the ground and not break off any roots, it would be something like a dumbbell with our hand grasping the stem and at either end the cluster of branching parts.

4. The Leaf and the Gall Fly. — The leaf of the apple tree has a big work to do. It is the principal factory of the tree. With the help of the sun it takes the water that comes

up through the trunk from the root and combines it with some parts of the air so as to form nearly all the material that the plant uses. The wood and starch that is in the stem and the sugar that is in the apple, as well as the material of the leaves themselves, are all made by the thin green leaf.

Not only must the leaf do this work but it must put up with many annoyances, at least we should call them annoyances if we were leaves and they happened to us. Leaves are tender and, as we know, many kinds are good to eat. There are insects that like to feed upon the apple leaf. One of the insects is called the *gall fly*, which lays its eggs on the leaf. These hatch into little worm-like creatures, which so irritate the leaf that it grows a little house around them to shut them in. Instead of harming the gall fly, however, this affords him food and shelter so that even the sharp-eyed birds cannot find him.

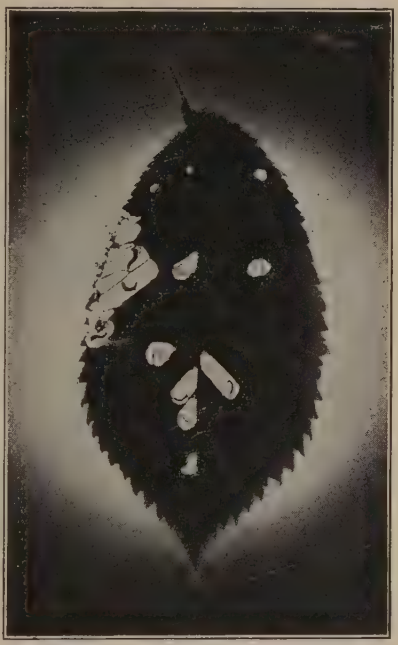

FIGURE 2. — LEAF-MINERS DESTROYING AN ELM LEAF.

There are some other insects, such as the leaf-cutting wasps, that cut out portions of the leaves and take them away to make nests. Perhaps there are a hundred kinds of insects (Figure 2) that feed upon the leaves of apple trees, and, of course, the leaf is not able to do its work when it is weakened by the attacks of insects.

5. The Stem and the Borer. — The stem, or *trunk*, of the apple tree supports the leaves, the branches, and the fruit, and its strength keeps pace, as a rule, with the added burden imposed upon it. In addition to this work it provides a path for carrying materials from the roots to the leaves and other materials from the leaves back into the roots. The trunk is also used for the storage of food. It contains the starch which the leaves have manufactured. This is food for some animals.

FIGURE 3. — THE FALLEN APPLE TREE UNDERGOING DECAY.

The *borer* is one of the insects which gnaws its way through the trunk of the tree, getting food from the parts it gnaws away, and at the same time hiding from the birds that might otherwise feed upon it. When many borers eat their way through a trunk, it is so weakened that it cannot do its work and the tree breaks off and crashes to the ground. Thus, the stem, like the leaf, is not able to do its work properly if it is attacked by insects.

6. The Root and the Grub. — Roots distribute themselves in proportion to the raw materials in different parts of the

soil. Where these substances are abundant, the roots are numerous, but where the soil is poor, the roots will not develop. Strong, numerous roots tend to produce a heavy, thick trunk which in turn tends to support strong, vigorous leaves.

Some roots discharge a substance which dissolves materials in the soil and thus use materials that otherwise they could not use. Roots hunt out the water in the soil and sometimes develop a large root system especially for the purpose of taking up water. Such a root system may develop in a water pipe if the root can find a break in it.

Roots, also, are attacked by animals and insects. The woody materials of which roots are composed are a good food for some animals that burrow in the soil. Certain insects lay their eggs in the branches of trees, and when the young hatch, they burrow through the stems, causing them to die and drop off, the young insect falling with them. When the twig dries up the young insect leaves it, burrows into the ground and feeds upon the roots there. The root, like the leaf and the stem, cannot function properly under these conditions.

7. The Blossom and the Bee. — When the apple tree is seven or eight years old and has a well-developed root system, a fairly strong trunk, and a good showing of branches, it begins to blossom. A blossom is the first step in the production of a fruit.

The blossom contains several parts: The pinkish-white color is limited to the small leaf-like parts (*petals*) which serve to attract attention; there is also a sweet fluid (*nectar*); and numerous minute *stamens* that produce a yellow dust (*pollen*).

The nectar serves no direct use for the apple blossom, but it attracts bees, which use the nectar to make their honey. Bees visit many flowers before they have all the nectar they can carry, and in going from flower to flower they carry

pollen from one to another. This pollen is necessary to the proper fruiting of the plant. The bee, therefore, renders a real service to the apple tree, for without this transfer of pollen from one blossom to another (*pollination*) very few apples would form. In this case we have an insect that is not an enemy to the tree but a most necessary friend. The blossom is able to do its work much better because it has insect friends which use it for their own advantage and in so doing render a service to the tree.

8. The Fruit and the Life Cycle. — When the work of the bee is done well and the weather is favorable the base of the flower develops into the fruit with seeds inside. The apple is green like the leaves, while it is young. It does not show color until it begins to form sugar, which makes it edible. We might say that the apple was advertising its sweetness, so that some animal would eat it and throw away the core. As the core contains the seeds, these may then find a favorable place to grow and may, in time, form new plants. This brings us back to our starting point, and we may say the tree has completed its life cycle.

FIGURE 4. — THE "WORM" IN THE APPLE.

9. The Story of the Codling Moth. — The material of the apple is food for large animals that eat it and drop the core. It is also food for small animals that live inside of it for a time. They not only eat it but they use it for a shelter and as a protection from their enemies. The "worm" so often seen in apples (Figure 4) is the young of the *codling moth* that laid its egg there just as the fruit began to form.

This worm is called a *larva*. The larva hatches from the

egg which the moth laid in the little fruit of the apple. Then it bores its way into the core and here it eats and grows and sheds its skin (*molts*) until it is full grown. Inside the apple it molts three times. Just before it is ready to molt again it bores its way through the side of the apple and makes its way to some protected spot, where it spins a silk-like nest (cocoon) around itself.

FIGURE 5. — PUPA OF CODLING MOTH.

After staying in the cocoon for a time, it sheds its skin once more, but this time we do not have a larger larva as in previous molts, but a new stage in the life of the codling moth begins that is called a *pupa* (Figure 5). In this pupa stage, it can take no food, for it has no mouth parts and it cannot move about, for it has neither legs nor wings. But it can wiggle and can take in air through the openings in the sides of its body. The length of time it remains in the pupa state depends on the temperature. Eventually, the fifth molt occurs, the adult moth emerges from the pupa (Figure 6), and in a few days the females are ready to lay eggs in favored places. This brings us back to our starting point, and we may say the codling moth has completed its life cycle.

FIGURE 6. — ADULT CODLING MOTH.

10. The Story of the Apple Tree Continued. — The mature apple tree bears fruit for many years. But insects continue to infest it until finally some of its branches decay and openings are formed in them where birds find a place for a nest. As time advances the branches weaken and the winds break off many of them. Decay progresses and eventually the tree weakens and falls. The wood is probably saved by the owner, who cuts it up into firewood and possibly burns it in a fireplace.

If we could see it burning, and could understand all that takes place during this operation, we should find that the work that the leaves did during years of patient labor is being rapidly undone by the flame. The substance that the leaves took from the air is going up the chimney and returning to the air in the same form as the leaves received it. This substance is a gas called *carbon dioxide*. The water that the leaves received through the trunk, which in turn was taken from the soil by the rootlets, is also going up the chimney in the form of water vapor to be returned to the earth again when it has been condensed into rain. The mineral substances that the rootlets took from the soil in solution are found in the ashes.

We might say that the elements involved in these processes have "completed their cycle." For example, the carbon which forms a part of the gas carbon dioxide was combined with other elements to make the starch in the leaves. This was converted into wood and served for a time in the trunk or branch or root until the tree decayed and was burned. Then through the action of the flame, it was reduced for a time back to carbon and further action of the flame joined the carbon and oxygen and it went up the chimney as carbon dioxide. All of the carbon, oxygen, and other materials of this tree are now in the air and soil, where the young apple tree found them.

When the trunk and limbs are cut into firewood, a short

stump is left in the field. The changes that begin to take place in the stump are similar to those that occur in the fireplace. The wood in the stump is attacked by the elements and small plants, the bacteria, and a slow decay begins (Figure 3).

After many years, the wood in the stump becomes soft and crumbles. In these changes all of the carbon, oxygen, and other materials locked up in the stump have been released and returned to the air and soil. This would have

Photographed by C. C. Carpenter.

FIGURE 7. — PICKING APPLES.

happened to the entire tree, if man had not wanted the wood to burn.

The apple tree, then, uses oxygen, carbon, water, and other substances in order that it may live. The codling moth does the same thing except that it obtains its food by eating the apple. When the codling moth dies, it decays like the stump and the materials in its body break up in a similar way.

11. Man and Budding. — When we told how the apple seed grows into a tree we did not speak of the kind of fruit

that this tree would bear. As a matter of fact the apples from this seed would probably be what is called "native fruit," small and sour and wholly undesirable as human food.

Man has found this out and he knows how to avoid it. When the tree is small he cuts a bud from an apple tree that he knows to be good. The favorite apples have names to distinguish them in the market. Some of the best known are the Baldwins, Greenings, Northern Spies, McIntosh Reds, Wealthy, Fameuse, Gilliflowers, and Spitzenberg. If we wish our little seedling to bear Baldwins, we go to a

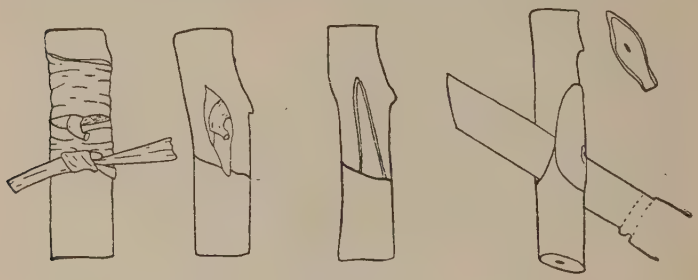

FIGURE 8. — SUCCESSIVE STEPS IN BUDDING.

Baldwin tree and take a leaf bud and place it in a slit in the bark of our seedling (Figure 8). This is called *budding*. If we have been careful, this bud will live and unite with the stock upon which we have budded it. Then all the rest of the tree above the bud is cut off and we have a tree bearing only one kind of fruit. We say it is common stock below the bud and Baldwin above. In nurseries thousands of these little seedlings a year or two old are budded to produce the well-known varieties we have mentioned above. These are then distributed to fruit growers throughout the country.

12. Grafting. — There is also another way in which the fruit may be changed. This is called *grafting*. We take

small branches of the desired tree and cut them wedge-shaped. Then we saw off a branch from the tree to be grafted, split the end that remains on the tree, and set our little branch in the edge of this wedge-shaped opening. If the cut parts are covered with grafting wax to keep out the water and prevent decay, the little branch will grow and bear apples like the tree from which it was cut. Many kinds of apples can be grafted on one tree so that one could pick early apples, medium apples, and late apples off the same tree. This is possible, but impractical. (See Figure 9.)

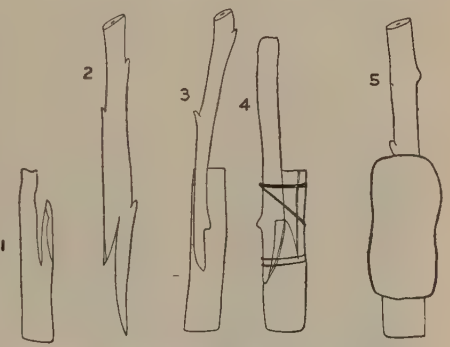

FIGURE 9. — SUCCESSIVE STEPS 1–5 IN GRAFTING.

13. New Varieties. Cross-pollination. — From time to time experimental fruit growers seek to improve the kinds of apples that are popular. Some apples have unusual flavors that are well liked but they do not ship well because they are tender and will not stand the jar and shaking of transportation. It is necessary to *cross-pollinate* in order to get new varieties. By this we mean taking the pollen from the blossom of one kind of a tree and putting it on the productive part (*stigma*) of a blossom of another kind. By so doing we try to combine the desirable qualities of both kinds of apples.

14. Man and His Competitors. — As we have seen, man is not the only animal that feeds upon the apple. We have mentioned the enemies of the leaf, stem, root, and fruit. Man must match his wit against these competitors if he is to secure a large crop of apples. Against the enemies of the leaves he uses a poison spray which kills the larvæ and

other enemies of the leaf. At the time the young fruit is forming, another kind of poison spray is put on the tree to kill the small larvæ that would enter the apple. Other

FIGURE 10. — HIGH-POWER SPRAYING MACHINE USED IN ORCHARDS AND CITY PARKS.

enemies of man and the apple attack the buds before they have developed and these must be subdued by a poison spray. Even after the apples are picked and stored, there is danger of injury to them by insect enemies. These are

held in check by putting the apples in cold storage, which prevents these insects doing further damage.

We have now seen through our study of the apple tree and its various associates just what we outlined in the opening paragraph of the book. We have noted (1) how apple trees live, (2) how they are related to one another, (3) how they depend on the physical world about them, and (4) how man can control them. These are the four central ideas in our study of biology, which we are now ready to define.

15. Biology Defined. — *Biology is the science that tells how animals and plants live.* No plant or animal is able to live unless it can go through all the changes we have just studied in connection with the apple tree. It must build up its body, provide for more plants or animals like itself, and finally break up into the very materials that originally united to form the substance of its body.

PROJECT

Now that you have gained an introduction to the idea of biology through your study of the apple tree, select some animal or plant and make a special study of its relation to the seasons, to water, to air, to soil, to food, and to man. These results should be written up and reported to the class from time to time during the year. At the end of the year, the observations which each one has been making should be turned in. In this way much interesting biological information about the living things in your immediate community will be collected.

OUTLINE

Biology, a study of living things
- The story of the apple tree
  - The sprouting seed
  - The plant and its roots
  - The leaf and its enemies
  - The stem and the borer
  - The root and the grub
  - The blossom and the bee
  - The fruit and the life cycle
- The story of the codling moth

Man's work
Budding
Grafting
Cross-pollination
Man's competitors
Biology defined

SUMMARY

Biology is the study of living things. Most of the important things in the world are alive, so it is interesting to see how they live. In studying this we learn their relations with one another and with the world about them, and how we can control them.

We chose the apple tree for this study because it is so familiar. We see how the seed sprouts and the plant sends its roots into the ground and its stem into the air to put forth leaves, blossoms, and finally fruit. In the fruit is the seed, which starts the life cycle all over again.

During this growth we see how the apple tree has a constant struggle with various insects and how man helps it in this fight by spraying. Man also controls the fruit by budding, grafting, and cross-pollination. In this way we see the four central ideas of biology: (1) how things live; (2) how they are related to one another, and (3) to the world about them; and (4) man's control over them.

QUESTIONS

Define Biology. What are its four central ideas? How is each of these illustrated in the story of the apple tree? What is the chief function of the root; the leaf; the stem? Name an enemy of the root; the leaf; the stem; the fruit. What insect is helpful to the apple tree? What do we mean by the *life cycle?* Describe the life cycle of the apple tree. In what ways does man control the enemies of the apple tree? In what three ways does man control the kind of fruit?

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CHAPTER II

IMPORTANT LIFE FUNCTIONS

It matters not how long we live, but how.
— Bailey

16. Life Functions. — We have just studied in a general way the life of an apple tree and some of its functions. When we inquire more carefully into the way plants and animals live, we see that they have several other features or functions in common. These are called the *life functions* or *processes* of all living things. They are sensation (irritability), motion, respiration, food-taking, nutrition (digestion, absorption, circulation, assimilation) excretion, and reproduction.

a. Sensation (Irritability). — Animals are sensitive to heat, to pain, to light, and to other outside influences which we call *stimuli*. Plants, too, respond to light and other stimuli. The response of animals and plants to stimuli is called *sensation* or *irritability*. It is an important life process or function, for it enables them to make the most of their location. Because of this function animals and plants are able to adapt themselves to their surroundings.

b. Motion. — All animals can move from place to place or move parts of their bodies. The higher animals move with ease as a result of highly developed muscular and nervous systems. The lower animals are more limited in their movements. The simpler plants move about in the water and at least the leaves of many of the higher plants move toward the sunlight, while some, like the hop-vine and morning-glory, not only grow but move in a certain definite direction.

Movement, then, in animals and plants is unlike the motion of the wind or of a flowing stream, because each living thing has to supply from its own body the energy required to move. Living things can change the direction and speed of their movements, but non-living things cannot. In biology *motion* is defined as the ability of living things to change their position without employing the force of the wind, or gravity, or similar outside agencies.

c. Respiration. — All animals and plants require energy in order to live. Part of this energy comes from food and part from the oxygen used in the process known as *respiration.* As a result of respiration the needed energy is obtained and a gas called carbon dioxide is formed. Respiration is the introduction of oxygen into cells and the giving off of carbon dioxide. Carbon dioxide is made up of carbon and oxygen.

Respiration, which takes place in every living cell, should not be confused with breathing. Breathing occurs only in the higher animals that have lungs. In breathing, air is taken into the mouth or through the nostrils and passes into the lungs, and the air in the lungs escapes through the mouth or nostrils to the outside. Breathing, then, is merely an adaptation to bring the oxygen of the air in contact with the blood vessels of the lungs.

d. Food-taking. — We eat in the morning, at noon, and again at night. If we have pets, we feed them regularly. The farmer has to feed his cattle, horses, and sheep when they are confined in the stables. In summer, when they are turned out to pasture, they secure their own food and eat at irregular intervals. The fox hunts at night or early morning as he captures mice or occasionally steals a chicken. All these illustrate another life function, *food-taking.*

There are a few plants, like the Venus fly-trap, that can capture insects and use their bodies as food. But this is not the usual way that plants take food. Food-taking is really

true only of animals, for the green plants manufacture their own food, chiefly in their leaves.

e. Nutrition. — This function includes first the preparation of food so that the animal or plant may have it in the form of a solution (liquid). This is *digestion.* Next, the food must be taken into the veins of the animal or plant. This is *absorption.* Then the food must be moved to all parts of the animal or plant. This is *circulation.* And, lastly, each part of the animal or plant must take from the blood or the sap the food that it needs. This is *assimilation. Nutrition* is the term under which are described the changes through which food passes from the time it enters into solution until it becomes a part of the living body of an animal or plant.

f. Excretion. — In a previous paragraph (*c*) the gas, carbon dioxide, was named as a product of respiration. Carbon dioxide is a waste product and is removed from the body of higher animals through the lungs and skin. It may pass directly into the air from the leaf of a plant or through the skin of the earthworm. The manifold activities of living things result in the production of other worthless products. A worthless or waste product to an animal or plant is one that does not yield it energy. *Excretion*, then, is the elimination of the waste products in the bodies of animals and plants.

The foregoing life processes have to do with the life of the animal or the plant itself. There is another life process that is important in keeping alive the races of animals and plants, namely, *reproduction.*

g. Reproduction. — All animals produce young or become extinct. It is common knowledge that all living things grow old and eventually die. And unless there were some provision for producing young, there would be no such thing as life. Before the bodies of animals and plants grow old, preparation is always made to produce more animals and plants like them. This has been the story since the beginning of life so far as science can determine; and it is the

only means by which there can be any increase in the total number of living things. *Reproduction*, then, is the process by which life continues from generation to generation.

17. Adaptation. — The fundamental functions tell us what the parts do in the life of the plant or animal. Adaptation shows how the structure responds to external conditions by means of changes in its form.

FIGURE 11. — SQUIRREL.

Notice how the squirrel holds the nut with his front feet. What use is made of the hind feet at this time? Are his front feet being used as hands or feet? Compare the tail of the squirrel with the tail of a mouse. Of what use to a squirrel is a big bushy tail? Would such a tail be useful to a mouse? Would it be a detriment? Why?

Every animal and plant is particularly adapted to its mode of life.

There are countless examples of adaptation. The squirrel is a good illustration. His toes are provided with sharp, curved nails that make it easy for him to hold fast to the rough bark of the tree; and, when he jumps from branch to branch, his tail acts as a parachute, so that his front feet alight first.

If a squirrel has more food than he can eat at once, he takes the nuts and buries them in the earth. In doing this he uses his front feet for digging a hole in the ground while holding the nut in his mouth. Name three different ways that the squirrel uses his front feet.

When you use a fountain pen in what ways is the hand adapted to the use of this instrument? First, you take it

from your pocket. Then you take the cap from the pen with one hand, while you hold it with the other. You place the cap on the top of the pen, the fingers exerting just the right pressure in removing it and forcing it on the pen.

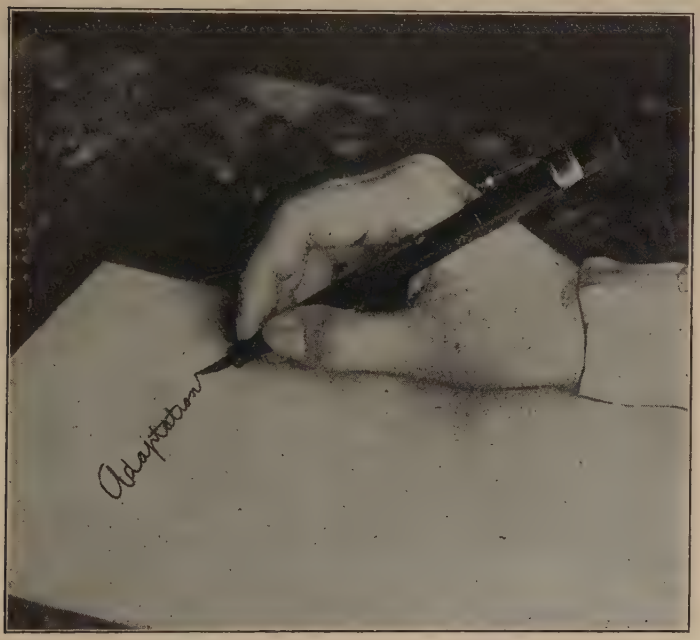

FIGURE 12. — ADAPTATION OF THE HAND.

Notice how the thumb and first two fingers hold the pen securely. The flat wrist gives a good sliding surface and the muscles are so controlled that the letters are uniform in size and shape. The nails of the fingers are adaptations and can be used to pick up small objects. The numerous joints in the fingers make the hand more serviceable. How many adaptative features of the hand can you think of?

Then you take the pen in your right hand and begin to write. The pen point is moved in the proper direction to make letters, forming accurate loops and curves because the hand has been trained to make these lines as you wish. It has be-

come especially adapted to do this work. In all this the thumb plays such an important part that man is sometimes called the "thumbed animal."

The various shapes of our teeth permit us to eat a great variety of food. In front are the chisel-shaped teeth for cutting; then come the tearing teeth on each side; these in turn are followed by broad crown teeth that crush and grind the food. Most fishes, frogs, and alligators have all

FIGURE 13. — MILKWEED SEED.
Distributed by wind.

their teeth conical in shape. Teeth of this shape serve only to hold the captured prey from escaping or to tear the flesh. The teeth of such animals do not show as much adaptation as those of man.

An extreme form of adaptation of the teeth is found in the elephant, which has two tusks, often several feet long. These tusks are really overgrown teeth and are used for protection. The trunk of the elephant is another unique adaptation. It is really the nostrils and upper lip greatly drawn out, and is used in browsing and in drinking, because the elephant's

huge bulk and short neck prevent him from reaching down to graze or to drink.

Did you ever think of the seeds of the maple tree that grow large wing-like vanes on the side (Figure 13)? The wind carries these seeds away from the parent tree and thus they have a better chance to grow. The dandelion and milkweed have downy tufts that carry the seed miles away from the place where the parent plant grew.

FIGURE 14. — HEAD OF EAGLE.
This shows the adaptation of the beak.

Many plants have special adaptations that help them to climb. The tendrils of the common pea and grape are such an adaptation.

The coconut has a buoyant husk that causes it to float in the currents of the ocean perhaps a hundred miles away till the waves carry it up on the shore, where it grows into a coconut tree. Some plants, like the wild geranium, hold the seeds by a spring that throws them several feet. All

these are adaptations that plants employ in distributing their seeds.

The main adaptations that have to do with the individual are: (1) *those that assist in food-getting*, such as the cutting teeth of the squirrel or the sharp curved beak of the hawk or the eagle (see Figure 14); (2) *those that aid in self-protection*, such as the rapid running of the fox or the color of a moth; and (3) *those that have to do with their surroundings*, such as the fins of the fish, for moving through the water, or the wings of the bird, for flying through the air.

OUTLINE

Life functions or processes	Adaptation
Sensation (irritability)	Specific illustrations
Motion	The squirrel
Respiration	Paws
Food-taking	Tail
Nutrition	The human hand
Digestion	Teeth of animals
Absorption	Wings of seeds
Circulation	General principles
Assimilation	Food-getting
Excretion	Self-protection
Reproduction	Surroundings or environment

SUMMARY

In this chapter we learn that all living things have certain life processes or functions in common. Two of these, sensation and motion, may seem at first less vital than respiration, food-taking, nutrition, and excretion, but really all are essential, for without the power to feel and to move the other processes could not be carried on.

While these functions have to do with the life of the plant or animal itself, reproduction continues that life from generation to generation. Adaptation is not a life process, but it is a very important phase of life, for everything in life is adapted in one way or another to the work it has to perform. This we see in the paws, teeth, and tail of the squirrel, the human hand, and even in the wings of some seeds, which are adapted to distribute them over wide areas. Most adaptations are to help in food-getting or in protection, or else in adjusting the plant or animal to its surroundings.

QUESTIONS

What are the life processes or functions? Do some seem more important than others? Are they in reality more important? What are the four processes of nutrition? Is reproduction a life process? Is adaptation? What adaptations has the squirrel for food-taking? For motion? What special adaptations has the human hand for the enormous variety of things it can do? Give other examples of adaptation in plants and animals. What are the three main objects of the various adaptations of plants and animals?

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CHAPTER III

COMPOSITION OF LIVING THINGS

The dust we tread upon was once alive.
— Byron

18. Matter, Organic and Inorganic. — We have seen that all living things carry on certain life functions. In this respect plants and animals are alike. These life functions are carried on by means of certain *organs*. For this reason all living things are called *organisms*, and are said to be composed of *organic* matter.

We cannot say this about water, rocks, soil, air, or iron. These substances are all non-living and are called *inorganic*. Wood, sugar, meat, oil, and coal are likewise dead, but each of them was part of some living organism before it became wood, sugar, meat, oil, or coal. How many other kinds of organic matter can you name?

Plants and animals each take into their bodies inorganic matter and make it a part of their bodies. These inorganic materials are then in the living substance and as long as they remain there, they are properly described as organic. The story of the apple tree and the codling moth revealed that all of the material in the bodies of these two organisms was eventually returned to the soil and air.

We shall have more to say about the terms *organic* and *inorganic* in the discussion of elements, compounds, and the materials of which organisms are composed.

19. Elements and Compounds. — The bodies of plants and animals as well as the earth and air are composed of a

great variety of elements and compounds. An *element* is a form of matter which cannot be broken up into simpler substances. Iron, carbon, oxygen, copper, and gold are elements.

A *compound* is a chemical combination of two or more elements in which each loses its distinctive properties. Water, sugar, olive oil, the white of an egg are compounds because each contains two or more elements united according to the laws governing chemical combinations. The starch found in wheat, potatoes, and corn is a compound of three elements, namely, hydrogen, carbon, and oxygen. Water is a compound made up of hydrogen and oxygen. Compounds are more numerous in nature than the elements. In fact, there are many thousands of compounds, while there are fewer than ninety elements.

A *mixture* is a blending of materials, in which each keeps its own nature and properties, as in lemonade. A mixture differs from a compound in that it is not formed by chemical action, and the elements of which it is composed do not lose their special properties.

20. Forms of Matter. — The elements and compounds which have just been discussed exist either as a gas, a fluid, or a solid. Each of these forms of matter has a technical meaning but for our purposes in understanding life processes, the following simple definitions are sufficient. A *gas* has neither definite size nor shape. There are no limits to the amount of expansion that may take place in it. The minute particles of which it is composed can move in any direction. If gas is confined in a glass bottle, the limits of its expansion will be the sides of the bottle. Air, steam, and hydrogen are gases.

A *liquid* has definite size, but takes the shape of the vessel containing it. The particles of which it is composed move over one another without any apparent resistance. It is not capable of indefinite expansion, and if placed in a bottle

it would not fill the entire bottle as would a gas. Water, milk, and oil are liquids.

A *solid* has definite size and shape and offers resistance to any change of these. In solids the particles are so firmly united that they are not easily separated. Such bodies retain their form independently of their surroundings. Sugar, wood, or rock are illustrations of solids.

21. Elements in Organisms. — Of the twenty-nine different elements that have been found in organisms, sixteen occur infrequently. The remaining thirteen are commoner and are believed to be essential to life. They are ox'ygen, carbon, hy'drogen, nitrogen, calcium, phos'phorus, sulphur, potas'sium, magne'sium, iron, sodium, chlorine, and sil'icon. It is interesting to note that these same elements are also the most numerous in lifeless things such as rocks, water, and the atmosphere.

22. Oxygen. — Oxygen is a gas which makes up a large part of the air. It is the element in the air which sustains life in animals and plants. Without it they cannot live. When given an undue amount of it, they develop at an abnormal rate. It forms about seventy per cent of the bodies of plants and animals.

The most striking property of oxygen is the ease with which it unites with other substances. Practically all cases of burning are caused by oxygen uniting with paper, wood, coal, or some other material. If a piece of glowing charcoal is placed in a jar of oxygen, it bursts into flame. This is the test for oxygen.

23. Carbon. — Carbon is, next to oxygen, one of the most important elements in biology. It combines with hydrogen and oxygen to form sugar, starch, fat, and wood. It is usually black and solid and is best seen as the charred remains of certain foods that have been overheated but not burned up, as when toast or meat is "burned." Carbon forms about fourteen per cent of the body of plants and animals.

24. Hydrogen. — Hydrogen gas is the lightest of all substances. It is found in nature combined with other elements entering into the composition of water, animals, and plants. It forms a little less than ten per cent of the bodies of organisms. It is an odorless, colorless, and tasteless gas.

25. Nitrogen. — Nitrogen is a gas which — unlike oxygen and hydrogen — does not burn. It dilutes the oxygen of the air and so makes it less active. Nitrogen forms less than three per cent of the body of plants and animals. Calcium, sulphur, phosphorus, iron, potassium, chlorine, silicon, and magnesium are the other important elements found in living things. None of these elements forms as much as one per cent of the body of plants or animals.

The human body is made up of:

oxygen	72. parts	phosphorus	1.15 parts
carbon	13.5 parts	sulphur	.147 parts
hydrogen	9.1 parts	potassium	.026 parts
nitrogen	2.5 parts	iron	.01 parts
calcium	1.3 parts		

26. Nutrients. — The elements above, while forming the body structure, are not taken directly as food. The foods we commonly use have these elements in combination with other materials. The foods that contain the proper elements are spoken of as *nutrients* or food compounds. These nutrients are starches, sugars, proteins, edible fats, and mineral matter.

a. Starch. — Starch is a nutrient that occurs in many of our foods. Potatoes, corn, wheat, rye, rice, and most of the vegetable foods contain large amounts of starch. Starch is easily changed to glucose by the digestive fluids. It furnishes some of the energy of heat and motion for the body.

b. Grape Sugar. — Grape sugar or glucose is a nutrient that occurs in grapes and in most other fruits. It is slightly different in composition from cane sugar or beet sugar.

Starch is always changed into glucose by the digestive fluids and never into cane sugar. The food value of both glucose and cane sugar is high. They are used by the body to furnish the energy of heat and motion.

c. Enzymes. — In the preceding paragraph it was said that the digestive fluids change starch into glucose. For many years it was not known what substances in the digestive fluids cause them to do this work. Now it is known that certain chemicals called *enzymes*, secreted by living cells, are the real active agents in digestion. The enzyme that changes starch to glucose is called *diastase*. Pepsin is an enzyme that digests protein. There are many other enzymes. An enzyme is not changed by digestion, so that a very small amount of it digests a large amount of food.

d. Proteins. — Proteins are nutrients that are found in great variety in our food. The proteins differ from starch and sugar in having nitrogen in combination with other elements. The characteristic element of protein is nitrogen. Each kind of protein has its own name. The protein in wheat is *gluten;* in beans it is *legumin*. *Casein* is the protein in milk and *myosin* is the protein in meat. The proteins are necessary in building and repairing the cells of animal bodies. If more proteins are eaten than necessary for this work, the surplus may be oxidized to furnish the energy of heat and motion or stored as fat.

e. Edible Fats. — The term *edible fats* is used to include both fats and oil. These nutrients are almost wholly energy producers. They are used chiefly to produce heat. As we go north or south from the equator, we find the native people adding ever greater amounts of fats to their diet, until we come to the Eskimos, who eat large quantities of pure fat with relish. Large amounts of fat are necessary to keep the body warm in the very cold zones.

27. Water. — This inorganic substance is not a food in the sense that it is broken up and digested as are real foods.

Because of its power to dissolve almost everything that is a part of animal or plant life, it is called a *universal solvent* and all foods are put into the form of solutions by the use of water. Blood is water in which are floating red and white cells and a great variety of foods and wastes. The tissues of animals and plants are soft in large part because of their water content. Our bodies consist of over seventy per cent water; there is some water even in bones. Water is necessary in the distribution of foods in all living things and in the removal of liquid wastes. The habits of wild animals which frequently travel long distances for water, and the severity of human suffering when water gives out as it sometimes does in the crossing of a desert, indicate how necessary water is in the daily life of higher animals. Animals are killed when the water in their tissues is frozen or when it is withdrawn in extreme evaporation.

Water is so familiar to us all that no special tests are necessary to identify it. It is easily resolved into the two gases, oxygen and hydrogen, which are united in the proportion of two parts of hydrogen to one of oxygen.

28. Mineral Foods. — In addition to the nutrients already mentioned which were starches, sugars, proteins, and edible fats, there are many minerals that are necessary for the proper development and growth of animals and plants. The essential elements of these mineral foods are: iron, sodium, potassium (potash), calcium, sulphur, and phosphorus.

Iron is necessary as a part of the red blood cells to enable them to carry oxygen from the lungs to all parts of the body. Sodium is needed to help the cells of the body to perform their work properly. Potassium (or potash as it is commonly called) is particularly necessary for the growth of plant cells and to a less extent animal cells. Calcium is a prominent part in the make-up of bones for animal skeletons, including the shells of clams and oysters. Phosphorus con-

tributes to the growth of cells of animals and is an important plant food.

Many foods that are deficient in starch, sugar, or protein are valuable because of the mineral foods they contain. For example, prunes contain iron, sodium, potassium, and phosphorus. Spinach has iron and sodium. Carrots have sodium and calcium. Peanuts have phosphorus and calcium. The foods just mentioned, along with many others, are necessary foods because of their mineral content and also because they are rich in what we call *vitamins*.

29. Vitamins. — The terms proteins, fats, carbohydrates, water, and mineral food do not completely describe all of the conditions that are necessary in a satisfactory diet for living things. There has recently been discovered a series of substances which are known as vitamins. Just what these substances are no one has found out but they can be proved to be present in our ordinary foods like milk, tomatoes, fruit, and lettuce. They will be discussed more in detail on page 304.

30. Organic Ash. — When coal is burned in the furnace, or wood in the stove, there remains a grayish product known as *ash*. In a similar way we should understand that in the burning of fuel in the body of organisms there are waste products which we might include under the comprehensive term of *organic ash*.

31. Physical and Chemical Change. — If a solid piece of ice is melted, it becomes liquid water. If the liquid water is boiled, it becomes steam or vapor, a gas. If the steam is condensed, it becomes water, which in turn may again be frozen into ice. Any change in a substance, which does not alter the material of which it is composed, is called a *physical change*.

On the other hand, when oxygen unites with wood, the wood burns, giving off heat and smoke, and ash remains. But this ash cannot be united with heat and smoke to form

the original wood. Such a change as is seen in the burning of wood is called a *chemical change.*

32. Energy. — Heat results from the burning of a candle or from the burning of fuel in the body of organisms. In this burning energy is set free. The heat from the burning candle is due to a rapid movement in the particles of the candle that is burning. The heat in organisms is due to a similar movement in the particles of pro'toplasm.[1] All of the material of our physical universe is in constant motion. These movements may be large enough to be seen or so small that we recognize them as heat only. They are also the source of light.

Energy is defined as the power to do work. It exists in two forms; active or *kinetic,* and stored or *potential* energy. Kinetic energy is the energy which a body has on account of its being in motion. Kinetic energy may be used in starting matter in motion, or in raising its temperature, or in altering the position of a body, or in producing chemical changes.

Potential energy is inactive energy such as the water stored or restrained by a dam, or the fuel properties in wood. The stretched watch spring in a watch has potential energy. An object cannot have potential energy except as the result of the previous expenditure of energy upon it.

The movements in animals and plants, the heat utilized by them, the growing of new parts, in short, all of the life processes depend upon energy. Not only are living things dependent upon energy to sustain life, but they are influenced by such forms of energy as heat, light, mechanical energy, and gravity acting upon the entire organism from without.

a. Temperature is an important factor in the life of organisms because in nearly all instances their life functions are possible only within rather narrow ranges of temperature.

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[1] The word *protoplasm* comes from two Greek words meaning *first form.* It is the original, simple material of which the cells (see page 44) of plants and animals are made up.

In general, life is possible only between freezing and boiling temperatures. Some living things can be temporarily frozen, for example the frog and certain fish, and later be revived, while a few of the lower plants live in the hot springs in Yellowstone National Park. But for most organisms these extremes are fatal, and we find them living best within a limited range of temperature.

The effect of temperature on life may be readily seen in the case of hens' eggs. In cold storage they will keep for months, but at the proper temperature they hatch into chicks in a few weeks.

b. Light has a direct influence on many plants, though not all parts of the higher plants respond to light. As a general rule the stem turns toward the light and the roots away from it, while the leaf will turn so as to expose its broad surface to the direct rays of light. It is important to remember that many living things are active only in the absence of light, or, as we commonly say, at night. It is hard to separate entirely the influence of light from that of heat because the two are constantly present, to a greater or lesser degree.

A striking illustration of the effect of light on the growth of living things is found in our dense forests. Spruces surrounded by large trees, thirty to fifty feet high which completely shut off the sunlight have been found to grow only six or eight feet in fifty or sixty years.

c. Motion. — The influence of motion or mechanical energy on the life of organisms is easily demonstrated to those who have an opportunity of studying the life in a rapidly flowing brook or observing isolated trees growing on a wind-swept hill. If the winds are largely in one direction such trees will have reduced the size and number of their limbs on the side from which the prevailing wind comes and will have much longer and more numerous limbs on the opposite side. The normal growth of plants can be greatly

altered if they are placed upon artificially moving platforms. The extent of the alterations will depend on the rate at which they are artificially moved.

d. Gravity. — Gravity is the attraction of the earth for all bodies. It is a form of energy that acts all the time and does not vary in amount. In this respect it differs from temperature, light, and motion. Stems tend to grow away

FIGURE 15. — THE FORCE OF GRAVITY.
Gravity pulled this spruce tree down, but it did not uproot it. Its stem still tends to grow away from the force of gravity.

from the force of gravity and roots to grow towards the center of the earth.

33. Conservation of Energy. — Every time that we wind a watch, we transfer the kinetic energy of our hand into the potential energy of the watch spring; and this potential energy in the watch spring in turn passes into kinetic energy in moving the hands of the watch. Thus energy is passed on and conserved. Let us see if we can apply this same idea to living things.

The light of the sun enables plants to grow and store up food in the form of sugar and starches. Ages ago there was a very luxuriant growth of plants in certain districts where coal is now found. These plants shed their numerous leaves, which were gradually changed into peat, and later covered by sand and clay and subjected to great pressure and heat. Under these conditions this organic plant material was transformed into *coal*. The ways in which this potential energy in the coal can be used serve as an illustration of the conservation of energy.

The light of the sun made plants grow which were later transformed into coal. The coal is burned under the boiler, making the steam which runs the engine. The engine turns a dynamo and produces electricity. The electricity is passed through a small wire in an electric bulb and furnishes light. Thus the light of ages ago is again made into light by this long process.

It has traveled in a circle so to speak. Energy may be converted into various forms. Electricity may be changed to heat, as in the electric flat-iron; into light, as in the electric bulb; or into motion, as in the trolley car. One form may thus be converted or changed into another form of energy. If energy is used in one form, it will appear in some other form. *Energy cannot be created or destroyed.* This is the law of the conservation of energy.

34. Conservation of Matter. — There is a similar law in regard to matter. That, too, cannot be destroyed. When a paper burns, it disappears as paper, but the matter of which it consisted still exists in the form of the ash which is left and the gases which passed off during the burning.

OUTLINE

Matter
- Kinds
  - Organic
  - Inorganic

Composition
- Elements
- Compounds
- Mixtures

- Forms
  - Gas
  - Liquid
  - Solid
- Important Elements
  - Oxygen
  - Carbon
  - Hydrogen
  - Nitrogen
- Nutrients
  - Starch
  - Grape sugar
  - Enzymes
  - Protein
  - Fats
  - Mineral foods
- Water
- Vitamins
- Organic Ash
- Physical and Chemical Change
- Energy, Kinetic and Potential
  - Temperature
  - Light
  - Motion
  - Gravity
- Conservation
  - Of energy
  - Of matter

SUMMARY

In this chapter we have seen how all matter, whether organic or inorganic, is made up of certain elements. There are a great many of these elements, but the most important ones in our study are oxygen, carbon, hydrogen, and nitrogen. These four make up a large part of the human body. Elements and compounds may be gases, liquids, or solids.

Food is required to maintain these elements in the body. The nutrients contained in food are the starches, sugars, edible fats, proteins, and mineral matter. Besides these there are certain body-regulators that are not classed as nutrients. These are water, vitamins, and organic ash.

These nutrients must go through certain physical or chemical changes to produce energy in the body. Active energy is called *kinetic*, stored or latent energy is called *potential*. There are many forms of energy such as heat, light, motion, and the pull of gravity, but energy can be neither created nor destroyed. And the same thing is true of matter.

QUESTIONS

What is the difference between organic and inorganic matter? Illustrate each. What is an element? Name several important ones. What is the difference between a compound and a mixture? In what forms is matter found? Is air a gas? Is steam? What four elements make up the bulk of the human body? Name the chief nutrients. How is starch changed into grape sugar? What is the chief function of proteins? Of fats? How does water help the nutritive processes?

What is the value of mineral foods? Name some foods containing vitamins.

What is the difference between physical and chemical change? What is energy? What is the difference between kinetic and potential energy? Is life dependent upon energy? Why? Name four important forms of energy. How does each one influence life? Explain the conservation of energy. Of matter.

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CHAPTER IV

THE GREEN PLANT AS A FOOD FACTORY

Man is dependent upon plants, which alone are able to manufacture food from the inorganic world.

— ATWELL

35. Introduction. — We have studied the life functions (Chapter II) and the composition of living things (Chapter III). But all life is dependent on food, and all food comes originally from the green plant. For this reason we are now to take up the study of the green plant, and to see just how it manufactures food.

36. The Green Plant. — Plants and animals require food for warmth, growth, movement, and the other life functions. Living things are continually using up the kinetic energy which they get from foods or nutrients. If life is to continue, there must be somewhere in nature a place where food is manufactured. This place is the green plant.

To illustrate this any green plant is satisfactory. The leaves of the apple tree which we studied in the first chapter will do. This process or function of manufacturing food is not present in animals or in the colorless plants. It is different from all the life functions defined in paragraph 15 and must not be confused with any of them.

37. Photosynthesis. — The primary activity of the green apple tree leaves is to *manufacture food.* In order to distinguish this process from all other life functions a special term is applied to it, that is, *photosynthesis.* This word is from the Greek, *phos,* light, *synthesis,* composition, and means putting together through the influence of light.

The raw materials which are used in this activity are water and carbon dioxide,[1] which are the waste products of oxidation. (Paragraphs 21–22.) The energy required to unite these two compounds is derived from the sun.

The water enters the roots of the apple tree, passes up the stem, into the branches and finally into the leaves. No water is obtained directly from the atmosphere. Only a relatively small portion of the water actually taken up by the roots is used in food manufacture as the greater part passes off from the leaves.

FIGURE 16. — CELL FROM FERN SHOWING CHLOROPLASTS (*c*) AND NUCLEUS (*n*).

The carbon dioxide used is derived almost entirely from the air where it is always present. The supply in the atmosphere is constantly being augmented as the result of oxidation in animals and plants, as well as in the non-living world, as, for example, in the rusting of iron.

The means by which these materials are combined is a green pigment, called *chlorophyll*, which is located in a special body or structure called the *chloroplast* (Greek, *chloros*, green; *plastic*, form). In the leaves of the apple tree these tiny green bodies (Figure 16) are numerous and round in shape.

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[1] When a fuel is burned, the chemical element, oxygen, unites either with the chemical element, carbon, or with the chemical element, hydrogen. When there is as complete a union of the oxygen and carbon as is possible, a gaseous product, carbon dioxide, is formed. This product is also known under the name *carbonic acid gas* and you are familiar with it in the bubbles of soda water. The oxygen that unites with the hydrogen forms water. Carbon dioxide and water, two of the products resulting from the burning of fuel, are described as inorganic.

38. Carbohydrates. — Foods consisting of carbon, hydrogen, and oxygen are called *carbohydrates*. One of the first of them that is manufactured is grape sugar, which is the basis on which the plant builds the remaining food nutrients. In the manufacture of sugar the oxygen which is not needed is released and given off to be used by either animals or plants in respiration.

It requires energy to combine water and carbon dioxide into sugar. Before this new combination can be made each of these substances must be separated, for in the new combination not all of the oxygen is needed. The energy for this process is derived entirely from light.

The importance of photosynthesis can hardly be overestimated. Through this special life process in green plants, potential energy is again made available in food. The green plant uses in its life processes some of the food which it has manufactured. This is the reason why the term *food-taking* does not apply to the green plant. The green plant manufactures a great deal more food than it needs for its own life processes, and this excess is stored in various parts of the plant.

The insects feeding on the leaf, the stem, and the root of the apple tree were absorbing some of this extra energy which the apple tree had manufactured and stored in leaf, stem, and root. Man and other animals eat the apple which could not grow without the food-factories in the leaves.

LABORATORY WORK

Demonstration of Photosynthesis. — To show that light is necessary for photosynthesis, fasten thin discs of cork to the upper and under sides of a leaf with clips, completely shutting off the light. Stand the plant in the bright light for half a day, then remove the corks from the leaf and the leaf from the plant.

Heat enough 60% alcohol to cover the leaf in a shallow glass dish. This may be done by setting the dish in hot water. Keep hot for half

an hour, or until the chlorophyll is removed from the leaf. Turn off the alcohol and put drops of weak iodine on the leaf. Note that the circle covered by the cork discs shows little starch or none, as indicated by the faint blue color or by lack of color.

Make a similar test by comparing a leaf from a plant that has been in the dark twelve hours with one that has stood in the bright light for the same time, using alcohol to remove the chlorophyll and iodine as a test for the presence of starch, as before.

39. Oxidation. — Oxidation means burning. It is the uniting of oxygen with any substance, and the giving off of carbon dioxide. We are all familiar with physical oxidation, as in the burning of a match or paper, where it is accompanied by flame, smoke, and heat.

Physiological oxidation takes place in all active organisms. It is a slow process without flame or smoke, but there is always heat, although this may not be apparent. Carbon dioxide and water are set free in this process much as they are when coal burns in a furnace.

We burn coal to keep us warm, to prepare our food, or run our machinery. We light a candle or an electric lamp to give us light. In all such cases the object is secured through the release of energy. When this energy has been released, we speak of it as heat or light. Oxidation in organisms is similar. In animals it is the source of heat and muscular power. An organism cannot carry on its life processes without using energy, but some very simple forms of life can stop using energy for months or even years. Thus some seeds of plants can be kept for two or three years but the statement that some seeds can live for hundreds of years is not true. These forms of life that temporarily cease carrying on their life functions are much like a clock that is wound up but not running. The potential energy is there and is only waiting for the necessary forces or conditions to release it.

LABORATORY WORK

Demonstration of Oxidation. — Take equal parts of potassium chlorate and manganese dioxide and fill a test tube half full. Hold the test tube over an alcohol or gas flame by means of test-tube holder. As soon as gas seems to be coming off from the mixture, insert a glowing match into the end of the test tube. Notice what happens.

Take a piece of picture wire and, after heating it, dip it in powder of sulphur. Heat it again until it burns and then place the burning end in the test tube containing the heated mixture. What happens?

Each of these operations illustrates oxidation in a striking manner.

40. Digestion. — The food energy which the codling moth larva secured by eating part of the apple would never be of any advantage unless it was digested. The energy stored in the leaf, the stem, and root of the apple tree, likewise, has to be digested before it can be utilized by the apple tree.

Digestion is the process of converting an insoluble food into a soluble form. The common nutrients all need to be made soluble before their energy can be used in a living organism. These changes are brought about by certain substances called *enzymes* or *ferments*. In plants they are produced by the living cells and in higher animals by the digestive glands. Their importance may be better understood from the illustration in the following paragraph.

Starch is a common food that requires digestion. It is easily changed to glucose (grape sugar) by the digestive fluids. Glucose is an easily absorbed nutrient of high food value, that occurs in grapes and in most other fruits. The enzyme that changes starch to glucose is called *diastase*. There are many other enzymes; *pepsin* is the one that digests protein. An enzyme is not changed by digestion, so a very small amount of it digests a large amount of food.

LABORATORY WORK

Demonstration of Digestion. — Artificial pancreatic juice is made by mixing 10 grains (1 gram) of commercial pancreatin and 20 grains (2 grams) of baking soda in 200 cubic centimeters of water.

Take 10 cubic centimeters of the artificial pancreatic juice in a test tube and to it add corn-starch paste. Set for two hours in a place where body temperature can be maintained. Test for grape sugar. This is done as follows: Add to the fluid in the test tube twice as much of Fehling's solution.[1] Gently heat the test tube until the contents turn first yellow and then brick-red. Grape sugar is the only substance that gives this color reaction.

Apply Fehling's solution to some corn-starch paste. Do you get the same color reactions? The changes which the artificial pancreatic juice caused are the same as those that take place in digestion. There are other digestive juices each of which acts on a definite kind of food. These changes are presented in detail in later sections.

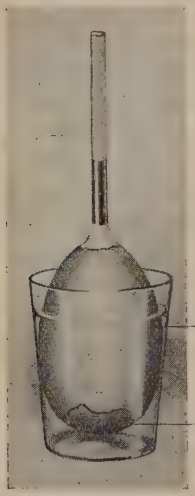

FIGURE 17. — OSMOSIS.

The water in the glass passes through the egg-membrane and forces the egg-white up in the glass tube; while the egg-white does not pass out into the surrounding water.

41. Osmosis. — All foods and gases that man, animals, and plants require enter the cells in the form of solutions. Foods of the higher animals are held in the stomach or intestine until they are able to pass through the lining membrane and eventually into the blood. Plant roots take from the soil minerals in solution to be used by the plant.

In both cases the process is the same. Solutions pass through these animal or plant cells before they can be used. In the case of plants, for example,

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[1] Fehling's solution is made by taking

(1) Copper sulphate	34.5 grams
Water	500 cc.

Set aside until completely dissolved. This is solution number 1.

(2) Rochelle salts	173 grams
Caustic soda	50 grams
Water	500 cc.

This is solution number 2.

Do not mix until ready to use, then take equal parts of each.

absorption of water and minerals and also of gases takes place in the root hairs. There is a transfer or movement of these substances through the cell wall from the soil, and this process is called *osmosis*.

In addition to the passage of water and minerals through a membrane in animals and plants there is also the passage of the dissolved gases, foods, and wastes. To summarize, *osmosis* is the passage of solids and gases in solution through a membrane.

OUTLINE

The Green Plant
- Photosynthesis
  - Carbohydrates
  - Demonstration
- Oxidation
  - Demonstration
- Digestion
  - Demonstration
- Osmosis

SUMMARY

All life depends on food, and all food comes originally from the green plant. In fact the chief function of the green plant is to manufacture food, which it does by a process known as *photosynthesis*.

These food products, largely carbohydrates, are digested by means of enzymes. They are then absorbed by the process of osmosis, after which the fats and sugars are oxidized or burned in the body.

QUESTIONS

Why is the green plant so important to us? What is photosynthesis? Describe the process in detail. How is carbon dioxide formed? Of what are the food products called *carbohydrates* composed? What is oxidation? What other process does it resemble? How is food digested? Describe osmosis.

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CHAPTER V

THE PHYSICAL BASIS OF LIFE

For men to tell how human life began
Is hard; for who himself beginning knew?

— MILTON

In the previous chapters we have studied the important life functions and the composition of living things. We have also seen how food is manufactured in the green plant, so that life may continue. We have referred to cells, but without giving a detailed explanation. We are now to take up a careful study of the *cell*, the unit of both structure and function in all living things.

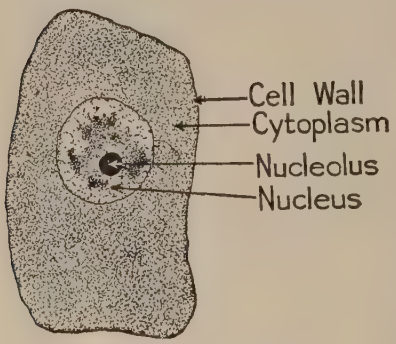

FIGURE 18. — A CELL.

42. The Cell. — When we take apart a plant or an animal we find that we can separate the parts until we come to a unit so small that it can be seen only through a microscope. These tiny units are called *cells* and are alike in the following respects: each one has a clear outer portion called the *cell wall* which incloses a mass of substance known as *protoplasm* (see page 31, footnote, and section 44, page 46). The protoplasm is made up of two parts. These are the *cy'toplasm* (Greek, *kitos*, hollow place; *plasma*, form), which is surrounded by the cell wall and

contains a sac-like body, the *nucleus* (nū′klē-us: Latin, *nucleus*, kernel, nut). The nucleus usually contains one or more separate bodies called *nucleoli* (nū-klē′ō-lī). A *cell* is defined, therefore, as a mass of protoplasm composed of cytoplasm and nucleus (Figure 18). Cells are so small that there are probably several hundred million of them in every human body.

The first man to give the name *cell* to a definite structure was the Englishman, Robert Hooke, who in 1667 made a thin slice of cork and placed it under a lens. He saw minute cavities in the cork which he called cells. What he really saw was the dead cell wall, and it was nearly a hundred years later before the living material in a cell was recognized and described as protoplasm.

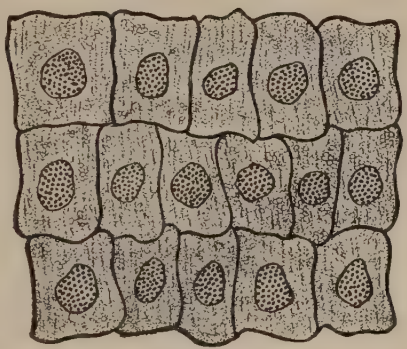

FIGURE 19.—SIMILAR CELLS UNITED TO FORM A TISSUE.

Compare these cells with the one shown in Figure 18.

43. Tissues and Organs. — The cells are of many shapes and sizes, and in the bodies of all but microscopic plants and animals they are united to help the plant or animal carry on its life processes. This union of cells to do a certain work is called a *tissue*, which is usually defined as a group of similar cells that do a similar work (Figure 19).

In all the higher animals the tissues are united into skin, arms, stomach, liver, lungs, kidneys, teeth, hair, and so on, or in plants into leaf, branch, stem, root, or flower. Such structures are called organs. An *organ* is a group of tissues that do a given work in the animal or plant. Organs form the parts of organisms (see page 24).

44. Protoplasm. — We have referred in section 42 and in the footnote on page 31 to protoplasm. This is the word used to describe the living material in all cells, in all living things. Protoplasm does not exist except in cells. One would expect that a substance so universally present in living things would be easy to describe. But it is hard because the living organism has to be killed before it can be studied. Protoplasm may best be described by comparing it with a familiar object, like the white of an egg, which is not protoplasm.

Protoplasm is a jelly-like substance that is neither a solid nor a liquid. It is usually colorless or slightly yellow. It can be stretched and when released, will, like rubber, contract. In appearance it is often clear though it may be opaque, and it may have either a fine granular appearance or a foamy structure like soap bubbles.

It is in the protoplasm that all of the life functions occur and for this reason it is called the physical basis of life. When we analyze it by chemical methods, we find the chemical elements already described as present in organisms. You should not think of protoplasm as a simple compound but rather as a mixture of several compounds that are *organized* to carry on the life processes. There is no chemical compound or mixture of chemical compounds that man has been able to put together that can be made to do just what the organized compounds in protoplasm have been doing ever since life began.

Living organisms were known for a long time before either the cell or protoplasm was discovered. In earlier times there was no instrument by which one could see these minute bodies that each of you now can see by simply looking through the microscope. The identity of the inventor of the microscope is in dispute. Hooke and Grew in England, Malpighi in Italy, and Swammerdam and Leeuwenhoek, both in Holland, are the names especially associated with early micro-

scopic observations. Leeuwenhoek became an expert lens grinder and made many different microscopes during his long lifetime. He possessed no less than 247 complete microscopes. From this very simple beginning in the seventeenth century, by men who liked to try experiments, we have developed the modern microscope. No single invention has contributed so much to our knowledge of the structure of organisms as the perfected microscope.

45. Environment. — The life functions which we have been discussing are processes present in every form of life at its very beginning. As soon as the apple tree's seed becomes a small plant this small plant has them, and just as soon as the egg of the codling moth hatches into a larva the larva exhibits each of them. These life functions, then, are passed from parent to offspring in the plant, in the animal, and in man. In marked contrast to these fixed factors of living protoplasm, there is a varying factor, the surroundings or *environment* in which organisms live.

A certain environment is necessary for the manifestation and continuance of life. Land animals, like the dog, die when kept under water; fishes cannot survive in the air; plants perish from lack of moisture; and nearly every living thing requires moderate heat and light.

Polar bears flourish in the extreme north, but would die in the Sahara Desert. Camels, on the other hand, can cross large stretches of desert without water, but would hardly survive a trip to the far north. Fish which are used to the pressure of the depths of the ocean burst when brought to the surface. Cotton will not grow in the north, but given a proper environment, the climate and soil of the south, it becomes one of our best crops. Thus we see that the development of every organism is dependent upon its environment. Man's superiority over the other animals is due in large measure to his greater ability to control his environment.

OUTLINE

The cell
  Wall
  Cytoplasm
    Nucleus
      Nucleoli
Organs
Tissues
  Protoplasm
Environment
  Contrasted with Life Processes
  Illustrated

SUMMARY

The cell is the unit of both structure and function for all living things. It is composed of protoplasm which is surrounded by a cell wall. This protoplasm is made up of cytoplasm and a nucleus, which in turn contains one or more nucleoli. All the tissues and organs of the body are made up of cells, which are the units of the life functions. These life functions are fixed, as distinguished from environment, which is variable.

QUESTIONS

Describe the cell. Of what is it the unit? Of what is it composed? What goes to make up organs and tissues? Are the life processes fixed? Is environment uniform? Illustrate your answer.

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PART II

APPLICATION OF BIOLOGIC PRINCIPLES TO ANIMAL LIFE

CHAPTER VI

THE GRASSHOPPER, AN INTRODUCTION TO THE STUDY OF INSECTS

And the grasshopper shall be a burden. — Ecclesiastes, xii, 5.

46. The Great Variety of Animal Life. — In the world there are about one million kinds of animals and more than one half of them are insects. These are so widely distributed, have such a great variety of form and color, and are so numerous that the age in which man lives is sometimes called the age of insects. While insects do not have any representatives that are large, compared with dogs or horses, they make up in number what they lack in size.

It is not the lions, rattlesnakes, or other large enemies that compete most with man for the domination of the earth, but the hosts of small animals of which the insects form the largest class. The building of the Panama Canal was as much a triumph over the disease-carrying mosquito as it was an engineering feat. Even to-day, many parts of the earth are uninhabitable because of mosquitoes.

The grasshopper, the potato beetle, the chinchbug, the scale insects, the codling moth, the gypsy moth, the army worm, and many others are taking a heavy toll each year from the world's food crops. The activities of these insects make food prices higher and it is in the interest of food con-

servation that more people should be aware of the common facts about insects. To do this it is necessary to get an idea of how they grow, how they get their food, what they eat, where their eggs are laid, how they reproduce, and how they may be controlled.

When we study rather closely the life history, structure, and activities of one insect, we have a fairly good idea of the great class of insects, for they are all much alike in many ways. All the fundamental life functions are performed by insects. All must have food, all must get oxygen, all have some way of self-protection, all reproduce, and all sooner or later die of accident, disease, or old age. Certain insects live as adults but a few hours, while elephants may live a hundred years or more. But all die in time and the young must come to take the places of the old if their particular race is not to become extinct.

Insects are always doing something. Some are flying from flower to flower, and you can watch to see what they are doing; others are busy on the leaves or the stems, and a few minutes of observation will show you whether they are friends or foes of the plant upon which you find them. The most interesting way to study insects is to watch them in their home life, but when this cannot be done, they can be well studied in the laboratory. Even in the city a surprisingly large number of kinds of insects can be collected by a class and brought alive to the laboratory.

47. The Grasshopper. — The typical insect chosen to begin our study is the grasshopper. When during mid or late summer we walk into the fields or along paths lined with grass, we are often surprised at the number of grasshoppers which jump away as we approach. They are of various sizes and kinds. Some are small and without wings, while others have small but well-formed wings. The difference in the wings and in the shape of the body tells us that there are various kinds of grasshoppers.

FIGURE 20. — FEMALE GRASSHOPPER.

Notice the position and shape of the modified legs at the end of the abdomen.

FIELD STUDY

Study living insects. Collect insects, such as grasshoppers, crickets, beetles, bees, wasps, flies, moths, butterflies, etc. Place some under tumblers and complete your report as follows:

	Where Found	Number of Legs	Number of Wings	Size of Wings	Size of Third Leg	Mouth Parts			
						Strong	Weak	Separate	Fused
House fly .	On food in the home	6	2	Small					
Grasshopper	On grass in the field	6	4	Medium					
Moth . .	On flowers in the park	6	4	Large					

48. Life Processes of the Grasshopper. — The young grasshopper must escape being eaten, must find food, must have oxygen to breathe, must be able to rid the body of waste substances, must be able to see, feel, and taste, must develop into an adult, and must do its part in providing for another generation of grasshoppers. If the grasshopper fails in any one of the first three of these it is unable to live, and conse-

quently the last and most important work, that of providing for the next generation, is not possible.

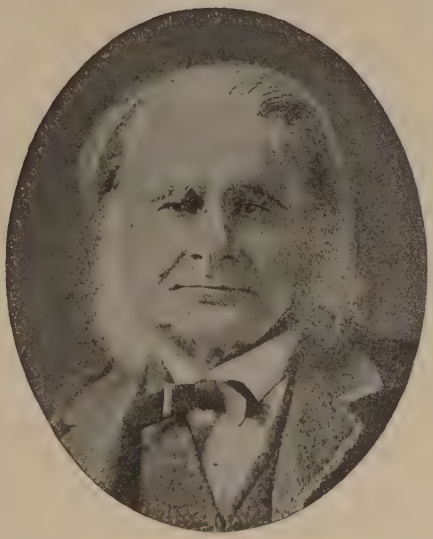
LABORATORY STUDY

Examine a live grasshopper. What are its means of locomotion? Compare its jump with its length. If in the same proportion, how far could a man six feet tall jump? How does the grasshopper obtain food? What protection from enemies does it gain from its color? Notice the division of the body into three regions: *head*, *thorax* (thō′-răks), which has wings and legs, and *abdomen* (ăb-dō′mĕn). How large is the head compared with the thorax and abdomen? The body is covered with a skin-like substance, known as *chitin*. This is called the skeleton of the grasshopper and because it is on the outside of the body it is termed an *exoskeleton*. How does it protect the grasshopper? When the living grasshopper is held between the thumb and finger, it "spits molasses." This is the partially digested food from its crop.

49. Protection. — When we look closely at the grasshopper, we find that it is provided with many adaptations which prevent its being caught and eaten. The most important of these are its color and markings. When a grasshopper jumps into the grass and remains quiet, its color so closely resembles the grass and the sticks that many of its enemies overlook it. The grasshopper is further protected by a pair of large eyes and by simple ears, which are located on the side of the body. By means of these sense organs, it becomes aware of the presence of enemies. The quickness of grasshoppers in jumping also helps them to escape being eaten.

50. Food-getting. — The grasshopper has little difficulty in finding its food. It eats leaves, and particularly the blades of grass. It does not need a keen sense of smell, as does the bee, which must search for flowers. However, the grasshopper has special smelling organs located in its antennæ (ăn-tĕn′ē), those long feelers which grow out from the head like soft horns.

The mouth parts which cut and chew the food consist of an upper lip and two teeth (mandibles, măn′dĭ-b'ls). The



Thomas Henry Huxley (1825–1895) was the father of the modern method of studying biology. Up to 1850 information about plants and animals was imparted only by lectures. Huxley found that science of his day contained many errors due to lack of first-hand information on the part of the writers. He corrected many of these errors by personal study of plants and animals, and devoted years to developing methods of laboratory study which enabled the student to gain his information directly. To-day these methods are accepted wherever the subject of biology is studied. This great English biologist made many important discoveries and was awarded numerous honors by his countrymen. Huxley showed great skill in putting the conclusions of science into simple language.

teeth are moved by powerful muscles which nearly fill the head. These mandibles work from side to side, instead of up and down as our teeth do. They are so effective that sometimes when grasshoppers become numerous they strip the grass of all its leaves, and even destroy growing fields of grain.

51. Respiration. — All animals have some way of getting oxygen to every portion of their bodies and of getting rid of carbon dioxide. The grasshopper has no lungs such as ours, nor does it breathe through its mouth. On either side of the abdomen are eight regularly arranged, small openings, spiracles (spĭr'-a-k'ls), which lead into branching tubes, tracheæ (trā'kē-ē). There are also two spiracles on the mesothorax. The branching tracheæ are kept open by means of skeleton-like rings so that the pressure of the muscles and other organs cannot flatten or close them. The tracheæ continue to branch until the subdivisions are so small that they can be seen only by aid of the microscope. These fine branches extend to the minute cells of which the body of the grasshopper is composed. Here the oxygen passes to the living protoplasm of the cells and carbon dioxide is given off to the air which is in these breathing tubes. This use of the oxygen by the protoplasm and the giving off of the carbon dioxide is *respiration*. (See Respiration, page 16.)

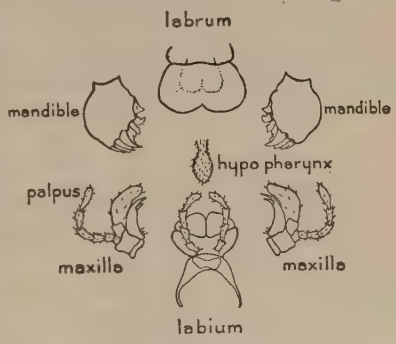


FIGURE 21. — THE LIPS AND TEETH OF THE GRASSHOPPER.

These show special adaptations which explain their peculiar shape and position. See if you can find out how each part is used when the grasshopper is eating.

52. Body Regions. — The grasshopper has three body regions: the head, the thorax, and the abdomen. Each

of these regions is adapted to particular kinds of work. The head structures are adapted to food-getting, seeing, and feeling. The thorax has appendages for locomotion: walking,

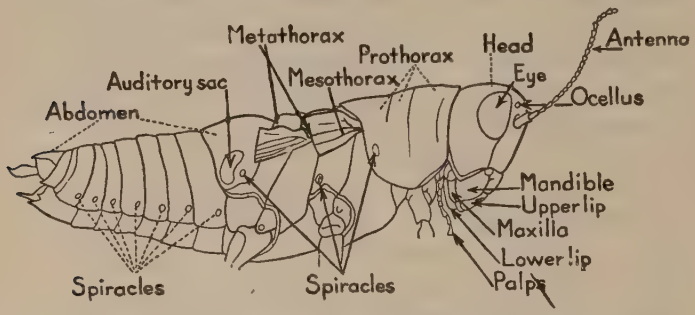


FIGURE 22. — IMPORTANT PARTS OF THE GRASSHOPPER.
There are eight spiracles in the abdomen and two on the thorax.

jumping, and flying. The abdomen is adapted to breathing, hearing, and reproduction.

The Head. — On the front of the head are three simple eyes and on the sides of the head two compound eyes. Near the simple eyes are two antennæ for feeling. The mouth has several special parts for food-getting. (See Figure 21, page 53.) These parts are an upper lip (labrum), and a lower lip (labium) for moving the food into the mouth. Inside the mouth is a pair of mandibles for cutting food and a pair of maxillæ with palps for carrying the food. The hypopharynx, a sort of tongue, is useful in handling the food.

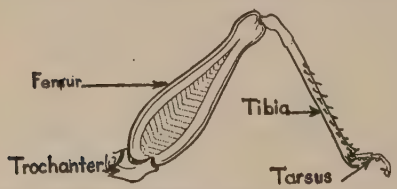


FIGURE 23. — THE JUMPING LEG OF THE GRASSHOPPER.
Why is the femur in this leg so much larger than in the one just in front of it?

The Thorax. — This is the second body region and it is composed of three parts. The prothorax, separate from the

rest of the thorax, is provided with the first pair of legs. The mesothorax, provided with a second pair of legs and the first pair of wings, is not clearly separated from the third part of the thorax, the metathorax. This supports the jumping legs and the second pair of wings (the flying wings), which of all these appendages are the most serviceable.

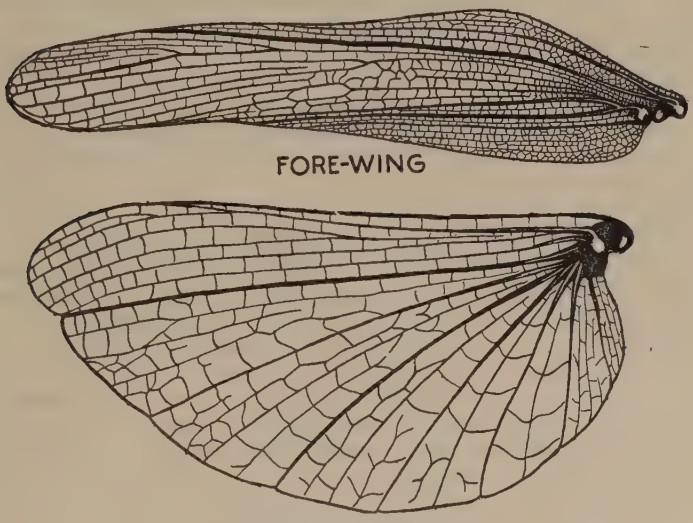


FIGURE 24. — FORE- AND HIND-WINGS OF THE GRASSHOPPER.

How does the grasshopper use each wing? What becomes of the hind-wing when the grasshopper is not flying?

The Abdomen. — This third body region is clearly divided into ten segments. The first segment, a partial one, contains the two auditory sacs, and two abdominal spiracles, one on either side. Fourteen other spiracles are found on the next seven segments, seven spiracles on each side. The last two segments have no spiracles. Instead they are modified for reproduction. The spiracles are used for breathing and the auditory sac, possibly, for hearing. In the

female the last segment of the abdomen is provided with two pairs of blunt spines that serve as an egg-laying organ called ovipositor.

LABORATORY STUDY

Work out the divisions of the body of the grasshopper: head, thorax, and abdomen; the position of eyes. How are the antennæ related to the eyes? How many distinct mouth parts are there? The teeth or jaws are the most useful in getting food. How do the jaws work? Sketch the head to show these parts with the mouth open.

Notice the attachment of the head to the thorax. The head fits into the thorax. The loose anterior (front) portion of the thorax is the prothorax (forward thorax). The first pair of legs is attached to it. Sketch the prothorax to show it and its legs. The portion of the thorax back of the prothorax is divided into two regions: the mesothorax (middle thorax) and the metathorax (back thorax). The line between them is not clear. Sketch these parts together with the legs and the wings. The jumping legs are attached to the metathorax; the outer wings to the mesothorax; the inner wings to the metathorax. The inner wings are used in flying. The leg of the grasshopper consists of: (1) a small section close to the body (the trochanter); a long muscular part free from spines (femur); a slender spiny part (tibia); and three segments of the foot (tarsus). The last segment of the foot is furnished with hooks which help the grasshopper in climbing, while the spines on the tibia prevent slipping as the grasshopper jumps. The large muscles in the femur of the last pair of legs, the spines on the tibia, and the hooks on the tarsus, are special adaptations which help the grasshopper in various ways.

Notice the tapering abdomen, composed of ten segments (rings), or parts of segments. Notice the depression and membrane in the first segment. This is the auditory organ, but it is not a true ear. Sketch the abdomen to show its features. The spiracles are located on the sides of the abdomen and thorax.

53. Excretion. — The gaseous waste, carbon dioxide, passes from the body into the spiracles and escapes into the air. The liquid wastes are collected by tubes that open into the intestine. If the grasshopper could not get rid of the waste substances that form in the body, it would be unable to live. But it has organs of excretion which remove

all these wastes from the body. If the grasshopper could use up entirely all the substances taken into the body, there would be little or no waste products. As the various nutritive substances become a part of the body of the grasshopper, some of the energy which they contain is so combined that it cannot be used by the living cells of the insect.

54. Nervous System. — The fundamental life process of irritability (sensation) in the grasshopper is performed by the nervous system. It consists of nerves and ganglia (a cluster of nerve cells) arranged in a row beneath the digestive canal and in the head. Nerves connect this central chain of ganglia, which are masses of nerve cells, with all parts of the body. On the head are found compound and simple eyes, special organs for feeling, the antennæ, and organs of taste on the mouth parts. By means of all these specialized nervous organs, the grasshopper is able to see, feel, and taste with a high degree of efficiency. Through these senses and that of hearing, it is made aware of food and enemies.

55. Reproduction and Life History. — In the autumn the female lays from 25 to 100 eggs in shallow holes which she makes in the ground. Some grasshoppers lay their eggs in decayed logs. The following spring the eggs hatch into small, wingless grasshoppers called nymphs (nimfs). (See Figure 25.) The nymph has a firm outer covering called an exoskeleton, which stretches but little with the growth of the nymph. Accordingly, at stated periods, the nymph sheds this exoskeleton, and grows until it fills its new exoskeleton. This shedding or molting continues until the fifth and last molt, when the nymph becomes an adult provided with wings and mature in every sense.

Adult grasshoppers may be found during the summer in meadows, flying and crawling and feeding on the leaves of grass, grain, and other crops. The adults mate and the females lay eggs to provide for the next generation.

56. Metamorphosis. — All animals which pass through a marked change in external appearance as they become full grown are said to undergo a *metamorphosis* (mĕt-a-môr′fō-sĭs: Greek, *meta,* change; *morphe,* form). These changes are more marked in such insects as the ants and bees than in the grasshopper. For this reason we speak of two forms of metamorphosis — complete and incomplete.

57. Incomplete Metamorphosis. — The newly hatched grasshopper, while very small, looks enough like a wingless grasshopper to be identified as belonging to the grasshopper family. Its form does not change materially from the time

FIGURE 25. — INCOMPLETE METAMORPHOSIS IN THE GRASSHOPPER.

it is hatched until it is full sized. Thus the grasshoppers become adult by a growing process termed *incomplete metamorphosis,* showing no marked change in form (Figure 25).

Complete metamorphosis will be discussed in connection with the butterfly or moth on page 94.

58. Structure and Classification of the Grasshopper. — In order to understand the grasshopper more fully it is necessary to find its place in the classification of animals. All known animals have been grouped into classes for convenience in study. The grasshopper belongs to the large class of animals called *Insecta* (ĭn-sĕk′ta: Latin, *in,* in; *sectum,* cut).

The *insects,* as a class, have their bodies divided into three regions — head, thorax, and abdomen. (See Figure 22.) All have three pairs of legs, and most of them two pairs of wings. They breathe by means of air tubes (*tracheæ*). In becoming adult, all pass through metamorphosis, either

complete or incomplete. The insect group is subdivided into fifteen smaller groups or orders.

The grasshopper belongs to the order known as *Orthoptera* (ôr-thŏp′tĕr-a: Greek, *orthos*, straight: *pteron*, wing). In the Orthoptera we find three common families: grasshoppers, crickets, katydids.

With permission of Nature Magazine.

FIGURE 26. — THE KATYDID.

The males of this insect serenade at night by rubbing the edge of one of the fore-wings against a file on the other. This gives the familiar chirping noise.

59. Economic Phases of the Grasshopper. — The grasshopper eats the leaves of plants, and if there are many grasshoppers they cause a serious loss of crops. The plague of locusts mentioned in the Bible refers to grasshoppers. In

some of the Western States years ago the grasshoppers came in great swarms year after year and destroyed annually crops estimated to be worth $200,000,000. But ordinarily, owing to the activities of their natural enemies, the number of grasshoppers does not become alarming.

Among the natural enemies of these insects that do much toward reducing their number are the birds. Some of the greatest destroyers of grasshoppers are the quail, bluebird, sparrow hawk, butcher bird, crow, red-winged blackbird, and kingbird.

There are other closely related insects that are harmful, as the cockroaches, the nuisances of the pantry, and the crickets that eat the roots of plants. There are also tree crickets which frequently lay their eggs in raspberry canes, killing the cane above the place where the egg is laid.

60. What Has an Animal Like the Grasshopper Accomplished by Living? — (1) It has used plants as food to build a complex body. (2) It has produced more grasshoppers. (3) It has used some stored-up food which might have been useful to cattle or sheep. (4) It has set free waste carbon dioxide which can be used by green plants to assist them in making food. (5) When it dies and decomposes, its chemical substances are returned to the soil and air to be used again by other living things.

OUTLINE

Animal Life
Large animals
Insects
Variety
"Age of insects"
Grasshopper
Life processes
Food-getting
Respiration
Excretion
Sensation
Body regions
Head
Thorax
Abdomen
Metamorphosis
Incomplete
Classification
Orthoptera
Economic phases
Accomplishment

SUMMARY

The vast variety of animal life makes advisable the study of types. For the insects, which are so numerous, we choose the grasshopper, which has life processes corresponding to those of other insects. The grasshopper has three body regions: head, thorax, and abdomen. Through these the life processes are carried out.

The grasshopper undergoes incomplete metamorphosis. It belongs to the class of *insecta* and to the order *Orthoptera*. It is of great economic importance as a destroyer of crops.

QUESTIONS

Which is the most numerous kind of animal? Are the large animals or the insects more important to man? Why? What divisions has the body of the grasshopper? In what way is he protected from his enemies? How does he get food? How breathe? How reproduce? Describe his nervous system; his life history. What is metamorphosis? What kind of metamorphosis does the grasshopper undergo? To what class and to what order of insects does the grasshopper belong? What is his economic importance?

CHAPTER VII

INSECTS IN GENERAL

The careful insect midst his works I view,
Now from the flowers exhaust the fragrant dew.
— Gay

We have just learned how the grasshopper lives. These facts about the life of this common insect are true about the lives of all other insects, for each one must have food, breathe, give off waste, and produce more insects.

61. What Is an Insect? — We have seen that the grasshopper is divided into head, thorax, and abdomen, has three pairs of legs, and air tubes for breathing. These same features are present in all insects. Most insects have two pairs of wings, but this is not true of flies or of some of the simpler forms which lack wings. While there are many differences in the size of these parts, the fact that an animal has this combination of structures defines it as an insect.

The numerical superiority of insects is due in large measure: (1) to their power of flight which helps them to escape from their enemies; (2) to their remarkable adaptations in color and habits which prevent them from being eaten, and enable them to live in every conceivable place and on every variety of food, some even eating tobacco and certain insecticides; and (3) to the production of large numbers of young, often several thousand in a single season.

Because of their reproductive activity, even minute insects become more destructive than the largest animals that

FIGURE 27. — COTTON PLANT.

Cotton cloth is made from the fibers which cover the seeds of the cotton plant. These are formed in the fruit, a kind of capsule known as a boll. The boll weevil, which is a beetle, is the worst insect enemy that has ever attacked the cotton plant.

have ever lived. Insects eat the food that the plant has made which man needs, and a few of them are intimately associated with such destructive diseases as malaria, typhoid fever, and yellow fever. Thus they not only destroy the food and economic products of man but directly cause his death. However, the argument is not wholly against insects for some of them produce such useful products as honey and silk. Thus owing to their universal distribution over the surface of the earth, and their importance to man, whether for harm or good, we are said to be living in the *Age of Insects*.

62. Economic Insects. — Economic insects are those which, because of their activities, are either helpful or harmful to man. By saying that an insect has no economic importance we mean that it does not harm us by eating things useful to us and that it does not help us in any way.

The struggle to live is a problem for all animals, for man as well as for the grasshopper. All insects must eat, and some eat the same things we wish to eat. Such insects we call harmful. Others aid the plants by carrying the pollen dust from one flower to another; others make honey. Such insects are useful. Certain other insects, like the fly, carry the germs of disease. These insects are particularly harmful, for they cause sickness and death.

Certain beetles eat dead flesh or bury dead animals by tunneling under them. Such insects are helpful. We should study insects in order to find out which are our friends and which our enemies. It would not do to kill all kinds of insects, for in many cases we should harm ourselves.

63. Classification of Insects. — So far we have avoided the technical names for the different classes of insects. But a knowledge of these terms will help us to find out more about insects in various reference books. For this reason we are giving below the most recent classification of the different groups or *orders*, as they are called. These need

not be memorized, but they will be found convenient for reference.

Order	Pronunciation	Derivation	Common Representatives
Orthoptera	ôr-thŏp′tē-rȧ	*orthos*, straight + *pteron*, wing	grasshoppers, katydids, crickets
Hemiptera	hē-mĭp′tē-rȧ	*hemi-*, half + *pteron*, wing	bugs
Coleoptera	kōl-ē-ŏp′tē-rȧ	*coleos*, sheath + *pteron*, wing	beetles
Thysanura	thī-sȧ-nū′rȧ	*thysanos*, fringe + *ura*, tail	fish-moths
Blattoidea	blăt-tō-ĭ′dē-ȧ	*blatta*-like, *blatta* an insect that shuns the light, a cockroach (Latin)	cockroaches
Siphunculata	sī-fŭn′cū-lā-tȧ	having a little tube (*siphunculus*, diminutive of *sipho*)	sucking lice
Hymenoptera	hī-mĕn-ŏp′tē-rȧ	*hymen*, membrane + *pteron*, wing	ants, bees, wasps, saw-flies, gall-wasps
Odonata	ō-dŏn-ā′tȧ	toothed (*odontos*, of a tooth)	dragon flies
Ephemerida	ē-fĕm-ĕr′ĭ-dȧ	short-lived (*ephemeros*, daily)	May flies
Plecoptera	plēk-ŏp′tē-rȧ	*plectos*, plaited + *pteron*, wing	stone flies
Trichoptera	trĭk-ŏp′tē-rȧ	*trichos*, genitive of *thrix*, hair + *pteron*, wing	caddis flies
Lepidoptera	lĕp-ĭ-dŏp′tē-rȧ	*lepidos*, genitive of *lepis*, scale + *pteron*, wing	butterflies and moths
Diptera	dĭp′tē-rȧ	*di-*, twice + *pteron*, wing	flies, mosquitoes
Suctoria	sŭk-tō′rĭ-ȧ	*sugere*, *suctus*, to suck (Latin)	fleas
Homoptera	hŏ-mŏp′tē-rȧ	*homos*, similar + *pteron*, wing	cicadas, aphids, scale-insects

In the preceding chapter we studied the grasshopper, a typical member of the Orthoptera. We shall now take up

several other orders of insects, with most of which we are already familiar.

64. Hemiptera. — One of the commonest orders of insects is the *Hemiptera* (hĕ-mĭp′tĕr-a: Greek, *hemi*, half; *pteron*, wing). To this order belong such common insects as the cicadas, plant lice, the woolly aphis, and the bane of the

FIGURE 28. — ADULT SEVENTEEN-YEAR CICADA AND NYMPH.

These insects, commonly called locusts, were abundant in the early summer of 1919 in the Eastern and Middle Western States. Did you see any of them? If you did not, you will have to wait seventeen years before you have another chance. There may be other breeds in the vicinity.

orchard, the San José (săn hō-sā′) scale. Some of these are very harmful. When the San José scale is allowed to feed freely, whole orchards may be destroyed. Plant lice injure apple, cherry, and peach trees, and the cabbage plant. The several kinds of scale insects which harm orchards may be killed by spraying the trees with a solution of lime and sulphur. The Hemiptera include the true bugs.

65. Cicada. — The seventeen-year cicada (sĭ-kā′da), commonly called the "seventeen-year locust," is one of the most interesting insects of the Hemiptera. The name is given to it because the nymphs (nĭm′fs), the immature stage, remain in the ground, actively feeding on roots, for seventeen years. There is another kind of cicada that remains in the ground for thirteen years. It lives in the Southern States.

Every thirteen or seventeen years, generally in the month of May, the nymphs crawl out of the ground, climb trees or fences, and molt into adult cicadas. The adult females lay their eggs in tender shoots of trees, causing the shoots to die. The young cicadas, after hatching in the shoot of the tree, go into the ground and begin their long period of larval existence which lasts thirteen or seventeen years. These cicadas are usually found in limited areas, but in these areas are very numerous.

The cicadas which we hear every summer are another kind, whose nymph lives in the ground for two years. As there are two broods of this species that appear in alternate years, the number does not seem to vary from year to year. Birds do much towards destroying them, the kingbird, sparrow-hawk, butcher bird, and great-crested flycatcher being their most common enemies.

66. Beetles. — These are hard-winged insects (Coleoptera) and generally noisy fliers. The first pair of wings is horny and meets in a straight line down the back. The second pair of wings consists of thin membranes. The mouth parts are for biting. Among the harmful beetles are many wood borers, the May beetles, potato beetles, asparagus beetles, and weevils. Some of the beneficial beetles are the ladybug, which feeds on destructive and harmful insects, and the carrion beetle, that feeds on dead animals.

The ladybugs are decidedly beneficial. Their larvæ run over leaves and feed on other insects. Even as adults they

continue this good work. Hop growers appreciate the value of both the larvæ and the ladybugs on their vines, as the ladybugs destroy the harmful hop lice.

The bird enemies of the beetle are numerous. Among the most important are the ring-necked pheasant recently introduced, the rose-breasted grosbeak, and the quail, which feed particularly on potato beetles. The English sparrow, cuckoo, and kingbird feed on the weevils. Robins, black-

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FIGURE 29. — BEETLES.

birds, and crows eat the white grubs, the larval stage of the May beetles. The woodpeckers destroy great numbers of borers by digging holes in the trees where the borers are tunneling.

67. Potato "Bug" or Potato Beetle. — Originally the beetle was found in Colorado feeding on wild plants of the potato family, whence its name of Colorado beetle. It gradually made its way east from one potato patch to another, being helped by the wild plants of the potato family that grew

where there were no potatoes. These beetles were also carried by trains that in a few hours took them hundreds of miles. They arrived in New York State in 1872.

68. Damage. — The potato beetle feeds on the foliage of the potato plant, thus injuring the size and quality of the tubers. This is due to the fact that most of the starch stored in the tuber is produced in the leaves and when the leaves are destroyed the amount of starch available for the tuber is lessened. Spraying must be carried on wherever potatoes are grown, to insure a good crop.

FIGURE 30. — THIS BEETLE IS THE FASTEST FLYING ANIMAL KNOWN.

69. Life History of the Potato Beetle. — The adult potato beetle passes the winter in the ground. In the spring the adults crawl out of the ground and the females lay their orange-colored eggs on the under side of the leaves of the early potatoes. In about a week or ten days the eggs hatch and the larvæ eat ravenously. In two or three weeks the larvæ reach their full size. They make their way into the ground, where they pupate for two weeks or longer, depending on the temperature. At the end of the resting stage, they emerge as adults and the females lay their eggs on the late potatoes for a second generation. The eggs hatch

into larvæ, the larvæ pupate in the ground, and the adults emerge in the fall. At the beginning of the cold weather the adults enter the ground and hibernate through the winter.

70. Natural Enemies. — Fortunately the potato beetle has many natural enemies. Adult lady beetles, popularly called " ladybugs," and their larvæ kill many of them. The tachina-flies lay eggs on the potato beetle larvæ and the young tachina-flies in the form of larvæ burrow into the bodies of the beetle larvæ, killing them in great numbers. Toads and snakes are enemies of the potato beetle and they take a heavy toll of them. The skunk is another enemy of the potato beetle, while crows, rose-breasted grosbeaks, pheasants, and quail destroy them in great numbers.

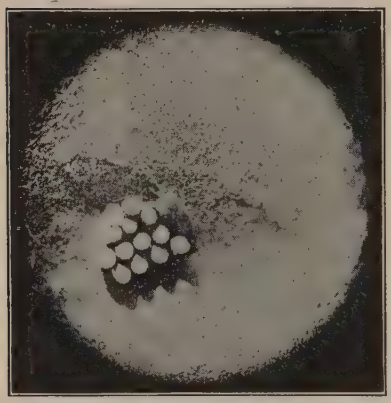

FIGURE 31. — EGGS OF LADYBUG (greatly enlarged).
You will need sharp eyes to find them in nature.

71. The Codling Moth. — Probably the most destructive of the *Lepidoptera* is the codling moth already mentioned in the first chapter. The larvæ spend the winter in the cocoon, pupate in the spring, and emerge as adults at about the time early apple trees bloom. The eggs are laid on the young apples about the time the petals of the blossoms fall and the larvæ begin to eat the growing apples, causing many of them to drop to the ground, or in any event, injuring the quality of the apple.

In one year the injury done by the codling moth to the apple and pear industry in New York State alone amounted

to $3,000,000. By applying a spray containing some poison just after the petals have fallen, the codling moths may be destroyed. The spray should not be used while the blossoms are fresh because then the helpful bees which visit them are killed and no harm is done to the destructive codling moths that come later.

72. Clothes Moths. — These are small moths with pointed and fringed wings. The adults emerge from May to August. They take no food and, after depositing their eggs on woolen material, soon die. It takes three weeks for the transformation of the pupa into the adult. More than one generation a season may arise.

The white, naked larva is about a half inch long and feeds on furs, feathers, hair, woolen materials, and museum specimens. The extensive destructiveness of these larvæ has resulted in many remedies. A full discussion of these will be found in Farmers' Bulletin No. 1353. A few of the more important are the following: (1) Constant watchfulness, for no treatment that kills the larva already in fabrics will have any lasting effects in keeping other clothes moths from depositing their eggs if the material is left exposed; (2) thorough brushing and beating if possible and placing the clothes in the sun before any treatment is applied; (3) careful wrapping in unbroken paper; (4) naphthalene and camphor for use in tight chests and trunks; (5) carbon disulphid. This chemical is excellent for the fumigation of closets which can be tightly sealed, and for trunks, chests, and other tight containers. When gaseous it is inflammable.

73. Tent Caterpillars. — There are several different kinds of caterpillars that spin webs in the trees in the spring and early summer. These are known as the *tent caterpillars* (Figure 32). The larvæ grow to maturity in about a month and during this time they feed on the leaves of the trees.

The details connected with the place and time of pupation vary with each kind of tent caterpillar. Some of them pass the winter in the pupa stage while others hatch in the spring from the fall batch of eggs.

FIGURE 32. — TENT CATERPILLARS.

They are seen resting during the hotter part of the day on the trunk of the apple tree. Later in the day they go out and eat the foliage. Note the great blankets of silk that they have spun on the side of the tree. Fortunately most of these caterpillars were attacked by ichneumon-flies, tachina flies, and chalcis-flies so that very few matured. The year following these destructive insect pests did very little damage owing to the successful campaign of their numerous insect enemies.

Here are found the apple-tree tent caterpillars and several kinds of tussock moths. The latter are very destructive to the leaves of shade trees.

74. Silkworms. — The silkworms belong to the same general group of spinning moths as the tent caterpillars. The larvæ feed preferably on mulberry leaves, although they will eat the leaves of the osage orange.

The larvæ feed for about a month before spinning their cocoons. The material for the cocoon is manufactured in the silk glands which open just beneath the mouth. It takes three or four days for the larva to make its cocoon, which is constructed of a smooth thread usually more than one thousand feet long. In a week or two pupation ends and the adult escapes from its silken home by moistening the cement that holds the silk threads on one end of the cocoon.

This insect is most valuable to man. It usually takes about three thousand cocoons to make a pound of raw silk and about ninety cocoon fibers are required to make a thread of sewing silk. Twenty-five to fifty thousand cocoons are used in securing enough material for a silk dress.

The silk-raising industry requires the detailed understanding of the habits of this domesticated insect. The cocoons from which the silken threads are secured are baked or steamed two or three days after the larvæ have completed them. This process kills the pupa, for cocoons from which the adults have escaped are unsatisfactory for the manufacture of silk.

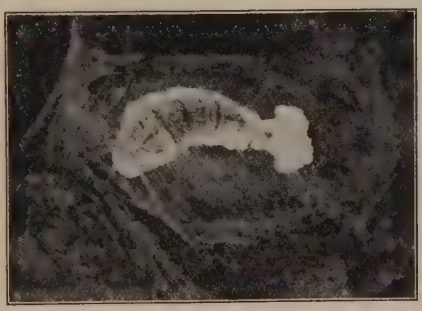

FIGURE 33. — WINGLESS FEMALE OF TUSSOCK MOTH.

She is laying eggs on the cocoon from which she has just crawled. After the eggs are laid she moves around for a time and soon dies of starvation, if some bird does not eat her in the meantime.

Three thousand six hundred years ago the wife of the third Emperor of China discovered the value of the silkworm. The method of making silk was a Chinese secret for two thousand years. About 555 A.D. two monks were induced by the Roman Emperor Justinian to bring the silkworm eggs out of China. This they did by concealing the eggs in cavities in their staffs. After this date the silkworm industry spread rapidly throughout Europe.

FIELD, LABORATORY, OR HOME STUDY OF MOTHS AND CATERPILLARS

These insects are easily collected and are interesting to study. From late in the spring until October you can find larvæ and pupæ. Some of the leaves upon which the larvæ are feeding should be collected.

The larvæ should be placed in jars provided with moist soil and some leaves. Arrange the cocoons and pupæ which you find as suggested in the following table.

Cocoon			Pupa			
Spun with silk only	Spun with a leaf	Spun with hair	Without cocoon	Suspended from one end	Suspended from one loop	Parasitized

Tent caterpillars spin cocoons and form small brown moths. Celery "worms" hang in a loop and form a black, swallowtail butterfly which feeds on the nectar of lilacs and the rhododendrons of city parks.

The black spiny caterpillars of the willows and elms hang free from the knot of silk and form the mourning cloak butterfly.

Tomato "worms" burrow into the ground and form a large-bodied, small-winged moth, a sphinx moth.

75. Lice. — Lice are small, wingless insects which were formerly classed with the true bugs. The mouth parts are adapted for piercing and sucking while in the bird lice there are nipper-like mandibles for biting instead of sucking. The bird lice feed only on the hairs and feathers and not on the blood as do the head and body lice. The feet of lice are armed with a very large curved claw which enables them to cling to the animal on which they feed, which is called their *host.*

The head louse of man deposits the eggs, which number about sixty, on the hairs of the head. These eggs usually hatch in six days. The head lice, notwithstanding the progress of civilization, are the most important of the external human parasites. They are commonly found in logging camps, jails, ships, in fact, wherever there is close association with people who are dirty. This was conspicuously true in the recent war.

The body louse is a different kind of insect from the head louse. It lives on the clothing and deposits its eggs on the clothing.

The eggs of lice are oval, whitish objects, commonly called "nits." The eggs of the body louse are glued to the fibers of the cloth and number about two hundred. They hatch in about six days. When the young hatch, they are like the parent, for there is no metamorphosis as in butterflies and moths. It has been conclusively proved that the body louse is an important carrier of the germs of typhus fever, relapsing fever, and trench fever. It is possible that as fleas move from one rodent[1] to another they may carry the germs of the dreaded bubonic plague, if their host harbors these germs.

FIGURE 34. — MALE AND FEMALE COOTIES. These vermin greatly annoyed the soldiers in the trenches and are carriers of disease. (Much larger than in life.)

Prevention consists largely in cleanliness, but this will not prevent temporary lousiness if there is association with unclean and careless companions. Lice are spread by contact such as the general use of combs and brushes or borrowed hats and caps. Body lice are scattered from person to person through the clothes and bed linen.

Head lice can best be destroyed by a thorough washing of the head with a two per cent carbolic acid solution or equal parts of kerosene and olive oil. When one of these remedies has been thoroughly rubbed into the hair it should remain for several hours, then be washed with warm water

[1] Rodents are gnawing animals such as rats, mice, ground squirrels and so on.

and soap. The dead lice and nits must be removed with a fine-tooth comb. Repeat this treatment after ten days to kill those that may have hatched in the meantime. Body lice are killed by sterilizing the clothing by such methods as baking, steaming, or fumigating.

76. An Immigrant Pest. — The European corn borer was introduced into the United States in 1909 and 1910 in broom corn imported from Hungary and Italy. This insect is a member of the moth family and is injurious in the caterpillar stage. Since its introduction it has spread over more than 7,696 square miles, and has been found in one hundred and eighty-five species of plants in the United States. In addition to corn, this pest is destructive of beans, beets, cotton, dahlias, hops, potatoes, sunflowers, swiss chard, and many other of the food plants of man and animals.

The European corn borer spends the winter in the tunnel made in the plant upon which it has been feeding. In April or May the borer, which is a caterpillar, spins a cocoon in the tunnel and in about nineteen days develops into the adult moth. After mating, the female deposits her eggs in small masses, each egg overlapping the adjoining egg in the manner of shingles. The females deposit about 350 eggs, on an average, but some lay more than a thousand. These eggs hatch in about seven days. The young borer soon begins to eat its way into the inside of the plant and within fifty days has again grown into an adult. Thus a second brood is ready to be hatched.

The females of this later generation lay more eggs, usually about 450 which are frequently deposited on or near the forming ears of corn. These eggs hatch in seven days and the borers begin their destructive feeding. The caterpillars of this second generation are the ones that pass the winter in the tunnels of the corn or other plant on which they have been feeding.

The name *corn borer* is given to the larva of several differ-

ent kinds of insects that burrow into the stalks and ears of corn as well as in flowering plants and weeds. Among these should be mentioned the corn-ear worm, the stalk borer, smartweed borer, celery-stalk worm, and larger corn-stalk borer. All of these have habits similar to the European

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FIGURE 35. — LARVÆ OF DESTRUCTIVE INSECTS.

They are exposed by cutting open the bundle of roots. This is one of the ways that insect pests are introduced in the United States.

borer and the larvæ are so similar that they cannot be distinguished, except by experts.

The seriousness of the destruction caused by the European corn borer has led the United States Department of Agriculture to place strict regulation on the importation from foreign territory of plants likely to contain this insect.

Control Measures. — Up to the present it has been found extremely difficult to control the spread of this pest. The following is taken from the Report of the New York State Entomologist, 1921:

It is advisable to emphasize the fact that special attention should be given to early planted corn because this is the most likely to be seriously infested and it appears probable that a very considerable reduction in the numbers of pests may be secured in single-brooded areas at least by concentrating effort upon the early corn.

1. Cut corn close to the ground, since many of the borers winter in the stubble.

2. Put as much of the corn into silos as possible because the borers are killed by the fermentation of the ensilage. This also applies to waste from canning factories.

3. Cut or shred corn stalks fed to cattle in order to promote their consumption. In any event keep the uneaten parts, the "orts," out of the manure and provide for the destruction by May 15 of the borers contained in all such materials whether in field, lot, or barn, by burning, plowing under, or submerging in water for some 40 days, unless the stalks are worked into piles containing considerable horse manure which will heat to such an extent as to destroy the borers.

4. Fall plowing, especially early and thorough, destroys many borers. It is considered advisable to encourage the practice in the infested areas. Heavy rolling prior to plowing has been suggested as a valuable aid, because many borers are killed by crushing the butts and it is then easier to turn the stubble under.

5. Weeds and other plants growing in or near badly infested corn may be invaded by borers in late August or September; consequently clean culture is of service in reducing the number of stems in which the pests may winter. Burning over in late fall or early spring of waste or weedy areas in or adjacent to corn fields, especially badly infested ones, is advised.

6. Corn stalks, cobs, and almost any thick part of all herbaceous plants may contain these borers under certain conditions and their shipment or removal from the infested area is dangerous and in many cases a violation of quarantine regulations.

7. Crops particularly likely to carry the borer, such as celery, beets, dahlias, etc., should not be grown in the infested areas within 50 feet of corn because the borers, deserting the corn for one reason or another, may crawl 30 feet or more before entering some other plant.

8. Where conditions permit, the probabilities of a general and possibly serious infestation may be considerably reduced by planting small areas of early corn, particularly near previously infested fields or ad-

jacent to sources of infestation, such as scattered corn stalks, for the purpose of attracting the moths. In case a serious infestation results, the borers in these small plantings may be destroyed by feeding the corn, or in some other manner. The main crop, if planted a little later, would largely escape the pest, if one may judge from conditions the last three seasons in the infested areas in both New York State and Ontario, Canada.

77. General Methods of Controlling Insects. — The details just given for the control of the European corn borer indicate that in this book, we can deal only with general measures for the control of insect pests. To simplify the consideration of the various methods they are discussed under (*a*) environmental factors, (*b*) poisoning, and (*c*) natural enemies.

(*a*) *Environmental Factors.* — Before any definite plan can be formulated for getting rid of insects, it is necessary first to understand their habits in detail. Insects that live in the ground and feed on the roots cannot be killed by the same method as those that feed on wheat and other cereals; and, in turn, those that feed on the leaves of fruit trees require a different treatment from those that live in the fruit.

It is also important that one understand thoroughly the influence of the environmental factors and their importance in the growth and number of insects. It is necessary only to mention such environmental factors as temperature changes, rainfall, winds, food supply, natural enemies, parasites, and preventive measures to realize that each of these plays an important part.

One preventive measure employed in controlling the number of insects consists in changing the crops so that insects that feed on corn, for example, will not be able to get suitable food if clover is sown after the corn crop. The expert farmer gives careful study to the proper rotation of crops in an effort to prevent the destructive insects from gaining too great headway.

(*b*) *Poisoning.* — Such measures as the above are applicable only to insects that live in the soil. Artificial methods must be used for the insects that live on and in plants. These consist in the application of poisons, the use of repellent substances, traps, and high and low temperature. The various insect poisons are known as *insecticides.* A good insecticide must be one that is effective, cheap, and a harmless poison to the insect host. The following poisons are most important in killing the biting insects: Paris green, arsenate of lead, arsenate of lime, hellebore. For sucking insects lime-sulphur wash, whale-oil soap, kerosene emulsion, tobacco decoction, and carbolic acid emulsion are used as contact insecticides.

Poisonous gases are used also in the control of insects. Here are employed carbon bisulphide, hydrocyanic acid gas, sulphur dioxide, tobacco.

A number of substances are known to act as " repellents " to insects and are frequently used to great advantage in preventing insect attack. Among such substances are: Bordeaux mixture, tobacco dust, carbolic acid emulsion, kerosene, turpentine, coal tar.

The common tangle foot, and various traps are successful in capturing flies.

Cold storage is very successful in preventing insects from developing, especially in fruit. Flour and meal are protected by raising the temperature sufficiently to kill the eggs or insects that may have gained access to them.

(*c*) *Natural Enemies.* — The natural enemies of insects are the birds and insects that prey upon them and the insects that live as parasites in them.

Through the investigations of the United States Department of Agriculture, a certain kind of ladybug (*Novius*) was found in Australia, which is the natural enemy of an insect pest (*cottony cushion scale*) that was destroying the orange trees grown in California. This scale is a plant insect which

was imported into the United States on young trees. Being freed from their natural enemies (*Novius*) which were not imported, they had increased rapidly. The prompt importation of novius put an end to the increase of the cottony cushion scale which is now of no great importance to California orange growers.

Entomologists throughout the world are working in the war against insects. Parasites which prey upon and damage insects and keep their numbers down in one country are constantly being drafted by scientists for use in the fight against the imported pests of another country. Many of the insects which have found their way into this country from other lands, left their natural enemies behind them. In consequence, they have been able to increase in great numbers, resulting in extensive damage to the plants and animals that they infest. In order to restore the balance of nature, the entomologist studies the life and habits of these insects in their own homes. He discovers what parasites prey on them. These are then collected and introduced into this country .

FIGURE 36. — CEDAR WAXWING.
Feeding its young a flying insect. One of our most beneficial birds.

The United States now has an expert in Mexico in search of parasites of the Mexican bean beetle and the Mexican fruit fly. Two experts are in Japan seeking the parasites

of the Japanese beetle and the gypsy moth. Others have been in Hungary, India, and France. The experts of all these countries are also studying insect pests, and they place their information in books, scientific papers, and government bulletins so that all the world may take advantage of their discoveries. This practice of publishing scientific information on these subjects is a great help in combating insect pests.

78. House-flies and Mosquitoes. — This group (*Diptera*) includes also the bot-fly, stable-fly, and cheese-skipper; also the beneficial bee-fly, wasp-fly, and tachina-fly.

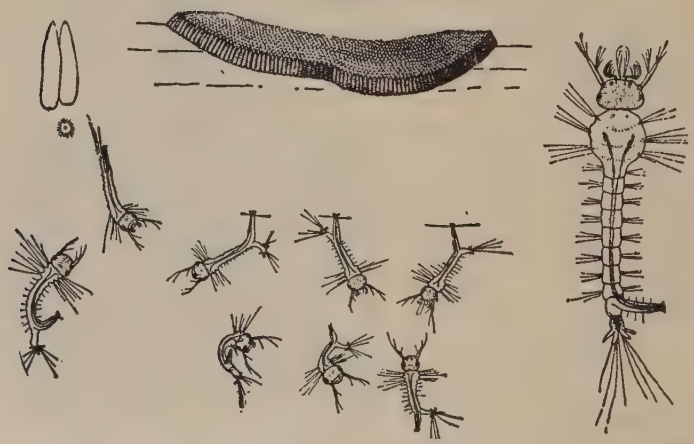

FIGURE 37. — EGGS AND LARVÆ OF MOSQUITO (CULEX).
Center, egg-mass and larvæ. Left top, enlarged eggs. Right, enlarged larva.

One of the most important members of this group is the common mosquito, which lays from two hundred to four hundred eggs in a raft-like cluster on the surface of the water in any stagnant pool or rainwater barrel. These eggs are usually laid early in the morning and, in favorable weather, hatch within twenty-four hours. The wigglers (larvæ)

keep to the surface when breathing but swim freely in the water for food. Food is brought to the mouth by vibrating cilia, which keep a current of water passing near them. From this water the wiggler collects his food. After seven days of this life it becomes a pupa, which, unlike most other pupæ, can move about. The pupæ remain at the surface of the water for air but descend by swimming when disturbed. The pupa stage lasts for two days, when the adult emerges and flies away after its wings are dried.

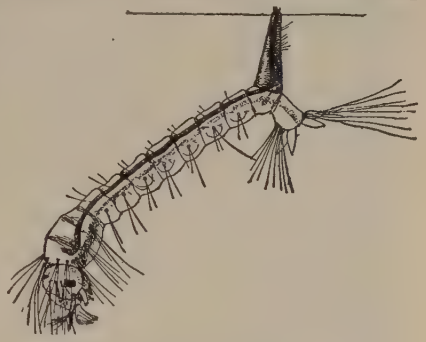

FIGURE 38. — LARVA OF CULEX IN BREATHING POSITION.

The time of these changes from egg to larva, from larva to pupa, and from pupa to adult depends on the temperature. Warm weather shortens the time and cold weather lengthens it.

In the United States there are three distinct kinds of mosquitoes. (1) The common mosquito is known by the technical name of *Culex* (kū′lĕks). It is not known that the Culex carries in its body any disease germs harmful to men, therefore it is regarded as harmless, although a source of great annoyance to those who frequent the woods or seashore during the summer. (2) *Anopheles* (ȧ-nŏf′e-lēz) is the scientific name of a second kind of mosquito, which is also generally distributed, but is not so numerous as the Culex. The Anopheles often carries in its body the germs that cause the disease called *malaria*. (3) *Aëdes*, formerly

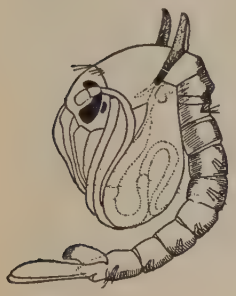

FIGURE 39. — PUPA OF CULEX.

known as *Stegomyia* (stĕg-o-mī′yȧ) is a mosquito common in the southern part of the United States. It is the insect which carries the germs of yellow fever from one person to another.

It is fortunate that the mosquitoes have so many enemies. The " wigglers " are preyed upon by the larvæ of dragon flies, by small fish, and by water beetles; while the adults are eaten by nighthawks, martins, bats, and dragon flies.

FIGURE 40. — POSITIONS OF CULEX (left) AND ANOPHELES (right), when at rest on a vertical surface.

Certain diseases caused by plants attack the adults and kill them in great numbers. (See Chapter XXIII.)

The number of mosquitoes can be greatly reduced by destroying their natural breeding places in old rain barrels, watering troughs, boxes that may hold water, pails, eaves-troughs, and sink holes. The larger breeding places are sluggish streams and swamps. Draining these is the most effective method of preventing mosquitoes from laying their eggs in such localities. When this is not possible, the surface of the water may be covered with kerosene, which kills

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FIGURE 41. — THE DRAGON-FLY.

One of the insects that feed on adult mosquitoes.

the larvæ by preventing them from getting oxygen from the air. Frequent applications of oil greatly reduce the number of mosquitoes.

79. The House-fly. — Because of its filthy habits of breeding and living and because it comes to the dining room and kitchen crawling over food, the house-fly has come to be recognized as a dangerous disease carrier.

Life History. — Each female lays from one hundred to one hundred and sixty eggs in stable filth or other refuse. The eggs hatch in a day or so into legless larvæ. In five to seven days, depending on the temperature and the food supply, the larvæ are full grown. They then pupate for another five to seven days. At the end of this time the adults emerge as mature flies ready to lay eggs for another generation. This continues until cold weather puts an end to their activities. Enough generations are produced every year so that a single female in the spring could have a million descendants by October if numerous enemies did not make this impossible.

FIGURE 42. — THE COMMON HOUSE-FLY.

Methods of Control. — Every one should support the "swat the fly" campaign and help reduce the number of flies. The few house-flies that survive the winter are responsible for the millions that swarm about in the summer. Their numbers may be reduced by several methods:

1. Begin early to kill the flies that are seen.
2. Remove all manure piles and make a general cleaning up of all refuse, thus destroying their breeding places.
3. Put fly traps on the covers of garbage cans to entrap all those that hatch as well as adults that go in to feed.
4. Keep many fly traps in operation in or about the house during the time of year that flies are active.

5. Poison those that do come in the house and keep fly paper ready for them at all times.

80. Tachina-fly. — This fly is beneficial to man. While it resembles the house-fly in appearance it has differences that may be clearly seen. It has long bristles on the abdomen and the bristles of the antennæ are bare. The tachina-fly lays its eggs on such larvæ as tent caterpillars, army worms, and many other destructive caterpillars. After these eggs are hatched the tachina larvæ bore into the bodies of the army worms or tent caterpillars and there feed until they consume them. Many kinds of caterpillars are held in check by the activities of these tachina-flies.

81. Parasitism. — If a plant or an animal feeds on a living plant or animal, it is an example of parasitism. In the above, the tachina-fly is the parasite and the tent caterpillar is the host. The animal on which the parasite feeds is called the *host*. If it feeds on the outside of an animal, like the mosquito, it is called an external parasite. If it feeds on the inside of an animal, as in the case of the tachina-fly larva, it is called an internal parasite. Lice and fleas are external parasites. In some cases parasitism is helpful to man, as in the case of the tachina-fly; in other cases, it works harm to man, as in the case of the anopheles mosquito.

82. Parasitic Flies. — This group of insects is decidedly beneficial. As an illustration we may use one of the larger ones known as *Thalessa* or the ichneumon fly (Figure 43). With long, thread-like drills this parasitic insect bores holes in trees and lays an egg at the bottom of the hole. The egg is usually laid near the burrow of one of the larger tree borers, *Tremex* (Figure 44).

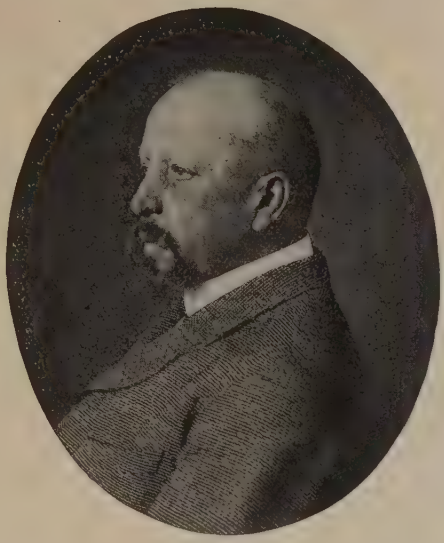
The larva of the Thalessa makes its way along the burrow of the Tremex borer and fastens itself to the body of the borer, upon which it feeds. In time the adult Thalessa emerges, ready to lay eggs which will destroy more of these enemies of the tree. But if the Thalessa parasites kill the

Tremex borer before it has eaten its way through the hard wood, all die together, because the Thalessa cannot cut an opening for itself.

83. The Work of the National Government in Insect Control. — During the past forty years Dr. L. O. Howard has been either assistant director or director of the Bureau of Entomology, United States Department of Agriculture. He and his numerous associates have been making discoveries about insects and applying to human welfare not only the new things that they have been learning about insects, but the new discoveries made all over the world.

FIGURE 43. — THALESSA LAYING EGGS.
The tree is infested with Tremex.

We may gain some idea of the amount and kind of work done in this Bureau by simply reading over the following subjects, each of which receives special study. Work on the gypsy moth and brown-tail moth; deciduous-fruit insect investigations; southern-field-crop insect investigations; investigations of the insects affecting the health of man; insects affecting the health of domestic animals; cereal and forage insect investigations; investigations of insects affecting forest and shade trees, forest products, and hardy shrubs; investigations of insects injurious to vegetables and truck crops; stored-product investigations; insects affecting tropical and subtropical fruits; bee-culture investigations.



Dr. L. O. Howard was born at Rockford, Illinois, 1857, and is still living. The year following his graduation from college, he became assistant entomologist in the Department of Agriculture at Washington. He remained in this official position until 1894, at which time he was made chief of the Bureau of Entomology. This position he still holds. He prepared definitions in entomology for the Century and Standard dictionaries. He is the author of *Mosquitoes — How They Live; The Insect Book; The House-Fly;* and many government publications. For many years he acted as the permanent secretary for the American Association for the Advancement of Science, the largest body of scientific workers in America.

Dr. Howard has devoted his main energies for the past forty years to applying the technical discoveries in entomology to human welfare.

The extent to which man can control the multitude of insect pests and utilize the beneficial insects is an important factor in human progress.

84. Insect Control in New York State. — The New York State entomological work is conducted as a part of the New York State Museum. There is a specially trained man in charge of the Department of Insects who is known as the State Entomologist, having his headquarters at Albany.

It is his duty to keep as complete a record as possible of the insects in New York State. Annual reports are issued describing in detail each year's work, for the nature of the work varies from year to year.

In a recent report the following insects are studied in detail: European corn borer, other corn insects, small-grain pests, insects affecting other field crops, the codling moth, shade-tree insects, and forest insects.

FIGURE 44. — TREMEX.

Just after laying eggs in a tree. The larvæ of this insect do much damage to trees.

85. Protective Resemblance among Insects. — Every one who has tried to catch grasshoppers appreciates how difficult it is to see them when they are not in motion. The colors of the wings and upper part of the body blend with the grass on which they feed. These colors are said to protect the grasshopper and the expression *protective coloration* or *protective resemblance* is used to describe this condition.

Butterflies and moths show protective resemblance (Figure 45) especially in those forms that have the upper sur-

face of the wings colored similarly to the trunks of trees on which these insects rest. Such dull colors are effective in obscuring them. The contrast in color is striking in all of these if we compare the brilliant colors seen on the hind wings when the insect is flying.

The exact interpretation of the meaning of the colors in insects is partly theoretical, and so we find authorities differing over the use and value of color. An insect whose

FIGURE 45. — A MOTH (CATOCALA) SHOWING PROTECTIVE COLORATION.

colors enable it to hide and lie in wait, making it more successful in catching its prey, is said to exhibit *aggressive coloration.*

In contrast to this form of coloration, we find insects that are believed to be unpleasant to taste and have bright colors on their bodies to warn the animals that prey on them that they are unsuitable as food. The conspicuous bands of color on wasps are said to warn animals that these insects have a dangerous sting. Such insects show *warning coloration.*

These conspicuously colored insects often have imitators but those insects in turn are not unpleasant to taste nor do they have a dangerous sting. This is known as *mimicry*.

HOME PROJECTS

How Insects Pass the Winter. All forms of life must adapt themselves to the winter season. If they are unable to do this, they perish.

Insects have adapted themselves in such a way that they pass the winter in some form or other. Certain insects live over the winter in the egg stage, as in the case of the tent caterpillar. Others like the Isabella caterpillar pass the winter as a larva. The cicada passes the winter deep in the ground as the nymph, while the cecropia moth is safe in a cocoon as a pupa. The mourning cloak butterfly is hanging in some protected place, in a barn or shed. The monarch butterfly has migrated to the southern states and thus escapes our severe winter weather.

How many other examples, such as we have illustrated above can you find? Favorable places for these various groups are old board piles and lumber piles, old buildings, fence rows, hedges, and vine tangles. Bring into class all cocoons, egg masses, chrysalids, spider cases, larvæ, and in fact anything that may prove to be alive in the insect line.

Individual members of the class may select one of the following problems to be studied and written up.

1. What do you find in searching the leaves of hollow stumps and logs in the woods?
2. What do you find in searching the lilac trees and tangles?
3. What do you find in searching the hedgerows and vines that climb on buildings?
4. What do you find in searching lumber piles and board piles?

5. What do you find in searching old buildings, barns, sheds, and other protected spots?

6. Make a terrarium for confining all the specimens that are brought in but keep it outside on the window ledge.

7. Sketch a landscape, roughly, which will show the area you covered and on it locate the position of the forms you found.

8. Identify and classify with the aid of insect books, government and state college reports.

OUTLINE

- Insects
  - Defined
  - Economic
  - Classification
- Hemiptera
  - Cicada
    - 17-year
    - 13-year
    - 2-year
- Coleoptera
  - Beetles
    - Potato bug
      - Damage
      - Life history
      - Enemies
- Lepidoptera
  - Codling moth
    - Damage
  - Clothes moth
    - Remedies
  - Tent caterpillar
    - Tussock moth
  - Silk worm
    - History
    - Economic importance
- Lice
  - Head
  - Body
  - "Cooties"
- Corn borer
  - History
  - Economic importance
  - Control measures
- General methods of control
  - Environmental factors
  - Poisoning
  - Natural enemies
- Mosquitoes
  - Culex
  - Anopheles
  - Aëdes (Stegomyia)
- House-flies
  - Life history
  - Methods of control
- Tachina-fly
- Parasites
  - Thalessa
  - Tremex
- Insect Control
  - National
  - State
- Protective resemblance
  - Coloration

SUMMARY

The number and variety of insects is so great that this is called the Age of Insects. Many that destroy our food-products are harmful, but some, like the bee, are helpful. Scientists have made an elaborate classification of insects, but the orders we are most interested in are the Hemiptera (locusts), Coleoptera (beetles), Lepidoptera (moths and butterflies), Suctoria (lice and fleas), Orthoptera (grasshoppers), and Hymenoptera (bees and ants).

The potato bug, codling moth, tent caterpillar, and corn borer are among the insects which do the most damage. It is hard to estimate the loss caused to our food-products each year by these insects. The clothes moth ruins thousands of dollars' worth of clothing and furs each year. Lice and fleas are an annoying pest. On the other hand silk worms furnish us with valuable clothing. Mosquitoes and house-flies are common carriers of disease. The tachina-fly and certain parasitic flies are beneficial to man. Many insects escape their enemies because of their protective coloration.

There are many ways of controlling insects. The Federal and State governments spend huge sums each year in this work. Rotation of crops helps to keep the pests from increasing. There are also many poisons, spread usually by spraying. Birds are natural enemies of insects.

QUESTIONS

What is an insect? Are insects helpful or harmful to man? Illustrate your answer. What is meant by *economic* insects? What are some of the best known orders of insects? Name some common representatives under each. What insects do our food most harm? Our clothes? Are mosquitoes and flies dangerous or merely annoying? What are cooties? Name two kinds of lice. What methods have the Federal and State governments adopted to control the spread of insect pests?

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Smith, Our Insect Friends and Enemies.

CHAPTER VIII

MOTHS AND BEES

The white moth to the closing vine,
The bee to the open clover,
And the gypsy blood to the gypsy blood,
Ever the wide world over.

— KIPLING

86. Moths and Butterflies. — There are more harmful insects among the moths and butterflies than in any other group. In the preceding chapter we studied some of them, the codling moth, clothes moth, tent caterpillar, and corn borer. But there are also many others, including tussock moths, gypsy moths, brown-tail moths, cut-worms, canker worms, and cotton-boll worms.

Butterflies are among the commonest and most attractive of insects. Many develop from larvæ that do no particular harm, and many of them, like the bees, help in pollination. As the butterfly goes from flower to flower, its head brushes against the pollen, which is thus distributed, making it possible for flowers to grow seeds. Among the more strikingly colored butterflies are the black swallow-tail, the larvæ of which feed on celery, parsley, and carrots; and the milkweed or monarch butterfly.

87. Life History of the Monarch Butterfly — Complete Metamorphosis. — The monarch butterflies arrive in the Northern States from the South, usually in June. Very soon the females lay eggs on the different kinds of milkweeds. The eggs hatch in a few days — the time depending on the temperature — into caterpillars that feed on the leaves of

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FIGURE 46. — MONARCH BUTTERFLY SHOWING SUCCESSIVE STAGES IN ITS METAMORPHOSIS.

the milkweeds. Each caterpillar has three pairs of jointed legs near the head and five pairs of leg-like structures along the posterior region that serve for clinging. The caterpillar (larva) molts and each time grows larger but does not show any signs of wings like the grasshopper. It is merely a larger caterpillar.

Just before the fourth molt it attaches itself to a leaf or stem and hangs by a knot of silk with its head down for a few days until it molts for the fourth time. After this molt it is a pupa without legs or mouth parts. It is yellowish green in color, with golden spots. During this stage there is a striking change taking place inside the green covering. Wings, new legs, different mouth parts with a long-coiled tongue, and a nervous system of a different form are growing into working order while this pupa hangs so quietly. After a few days the green pupa case breaks open and the adult crawls out with the wings crumpled. Within a few hours the wings expand and smooth out their wrinkles, and the moth is ready to fly away to feed on the nectar of flowers. This development is called *complete metamorphosis.*

Complete metamorphosis may be defined as the series of changes through which the insect passes from egg into caterpillar, then into pupa, and finally into full-grown moth. Ants, bees, butterflies, beetles, and certain other insects undergo a complete metamorphosis.

LABORATORY STUDY

The adult monarch butterfly has the body divided into head, thorax, and abdomen. How do these parts compare in size with the same regions in the grasshopper? Compare the legs and wings with those of the grasshopper. Which of these two insects is better adapted to flying? To jumping? Draw the entire animal. Draw wings and legs.

Gently rub the finger on the wing, and as the dust comes off, the wing looks more like the wing of a fly or bee. The lines that run lengthwise of the wing are the veins. Draw the wing.

Observe the mouth parts of the caterpillar to see how they are adapted to obtaining food. Notice the antennæ or feelers and the upper and lower lips. Compare these with the corresponding parts of the grasshopper.

The mouth parts of the butterfly are united into a single long tube which is the coiled tongue-like structure, called the proboscis (prō-bŏs'ĭs). Unroll it and see how its length compares with the length of the body. The butterfly uses the proboscis to suck nectar from flowers. Compare these mouth parts with those of the grasshopper.

FIGURE 47. — YOUNG TOBACCO WORM, A CATERPILLAR.

One of its insect enemies has laid eggs in its body, which have hatched into caterpillars. These caterpillars, in turn, have fed upon the tobacco worm until it was time for them to pupate. They then ate their way out of the body of their host and spun their cocoons, which are attached to the surface of the body. What will happen to the tobacco worm?

88. Enemies of the Moths and Butterflies. — Butterflies would become a scourge were it not for their numerous enemies. Chief among these enemies are the parasitic flies (§ 80), the females of which lay their eggs on the bodies of many kinds of caterpillars. When these eggs hatch into small larvæ, they burrow their way into the body of the large caterpillar, feeding upon the juices and tissue of their host. These larvæ are called parasitic because they get their living directly from another animal.

The parasitic fly larvæ grow rapidly and before the caterpillar dies they reach the stage at which they turn into pupæ. When they are ready to pupate, they eat their way out of the body of the caterpillar and spin a cocoon which in some cases remains attached to the body of the caterpillar (Figure

47). These parasitic larvæ so weaken the caterpillar that it dies.

Other enemies of insects are the birds. Many birds live entirely upon caterpillars and we find birds that seek them as food in all stages of their development and growth. The eggs laid on the twigs and trunks of trees are eaten by chickadees, nuthatches, brown creepers, and woodpeckers. The larvæ are eaten by many birds, notably by cuckoos, bluebirds, wrens, blackbirds, orioles, blue jays, crows, and house sparrows. The cocoons and pupæ are sought by the chickadees, woodpeckers, nuthatches, and brown creepers. The adult insects are preyed upon by house sparrows, chipping sparrows, and the whole group of flycatchers, including the kingbirds and phœbes.

89. Bees. — In contrast to the moths and butterflies which are probably the most destructive order, we find the

FIGURE 48. — HONEY-BEES (twice natural size).
a, worker; *b*, queen; *c*, drone.

bees, which are the insects of greatest value to man. The honey-bee and the bumblebee are economically the most important of the group. The honey-bee is valuable for its honey and wax and as a distributor of the pollen (Figure 48) which is necessary to produce seed. The bumblebee is valuable mainly as a distributor of pollen.

Honey-bees afford a splendid example of community life among insects. In the wild state they live in trees and caves. All wild honey-bees in this country have escaped from hives. In a honey-bee colony there are three classes of bees — the perfect females or queens, the males or drones, and the imperfect females or workers (Figure 48). There are generally one queen, a few hundred drones, and twenty to fifty thousand workers.

FIGURE 49. — THREE QUEEN CELLS.
In the brood comb of the honey-bee.

In a normal colony the queen alone lays eggs. She can lay an unfertilized egg which hatches into a drone or she can lay an egg which is fertilized. This fertilized egg hatches into a queen or worker, according to the food and the size of the cell which are provided by the workers. Thus the decision as to whether the young bee shall be a queen or a worker rests with the workers themselves. They also have the power to supersede the queen, or to raise a new queen in case of the sudden death of the old one. These powers are rightly intrusted to the workers — the great majority.

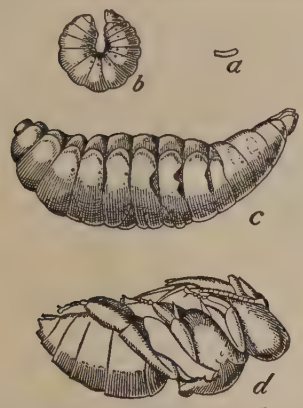

FIGURE 50.—*a*, HONEY-BEE EGG; *b*, YOUNG LARVA; *c*, OLD LARVA; *d*, PUPA.

The eggs are placed by the queen in cells (Figure 49), and after hatching are fed by the young workers, called nurses. The larva (Figure 50) is fairly bathed in food. In a few days it is full grown and then pupates. The workers now cap over the cell with

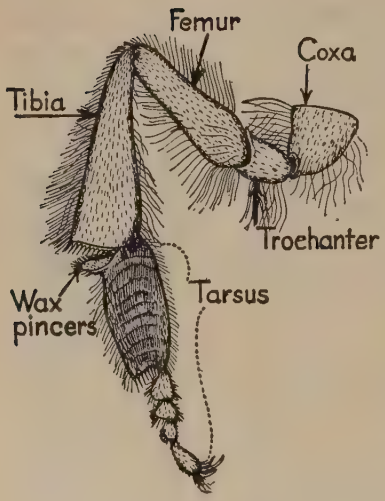

FIGURE 51. — INNER SURFACE OF LEFT HIND LEG OF WORKER.

wax, and in about twenty-one days the young bee cuts away the cap and crawls out — an adult provided with the four wings, mouth parts, antennæ, and the six legs of the honey-bee (Figures 51 and 52).

Workers are provided with the sting which is a weapon of both defense and offense (Figure 53). The queen has a small sting and the drones have none. When bees sting large animals like men, horses, and dogs, their sting is pulled out and with it parts of the internal organs, thus causing the death of the bee. When bees sting other insects or even one another the sting is not lost.

Sometimes swarms which have few bees and little honey are attacked by bees from other colonies. It is a pitched battle until the "robber bees" are beaten back or the defenders are themselves killed. The sting is used in these battles.

Bees are instinctively sanitary. If a large bumblebee enters the hive, the

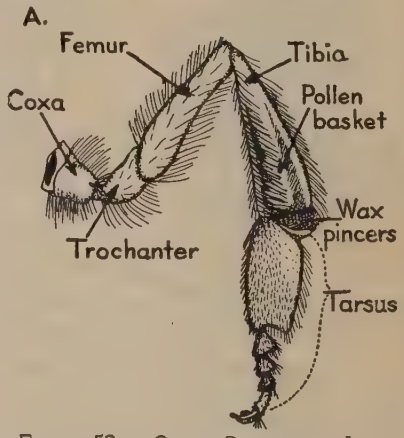

FIGURE 52. — OUTER SURFACE OF LEFT HIND LEG OF WORKER.

bees kill the intruder and usually, finding him too large to be taken out, embalm him by injecting the sting repeatedly into his body. The result of this operation is to make the bumblebee harmless to the colony. Sometimes they cover the body of a small, dead animal with a case made of propolis (prŏp′ō-lĭs), a substance the bees gather from certain buds. This serves to protect the colony from the effects of the decomposition of the body.

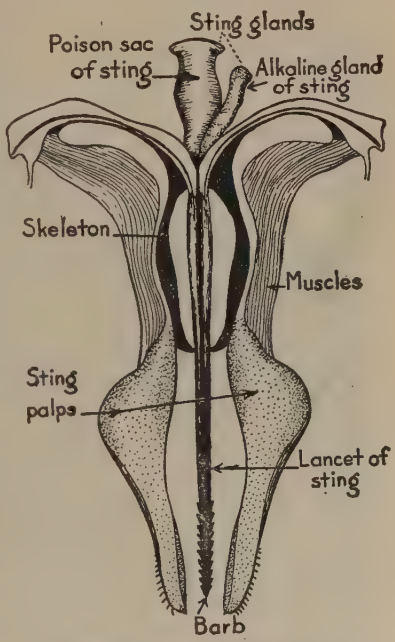

FIGURE 53. — THE BEE'S STING.

It is provided with barbs and a small amount of formic acid as an adaptative feature. Being located at the end of the abdomen, it can be turned in any direction. Notice the barbs on the sting. These point backwards and are adapted to cling to the surfaces through which it is forced.

At irregular intervals during the early spring and summer, bees have the peculiar habit of *swarming* (Figures 54 and 55). Several reasons for swarming are given by bee-keepers but no one pretends to be certain that he really knows the cause. It is a sort of revolt of the bees against their condition. Two of the commonest reasons given to explain swarming are the lack of room for the growing colony and lack of food.

When bees swarm, they usually alight on the limb of a tree and form a dense cluster. Here they hang from fifteen minutes to an hour before leaving for the woods. In a few cases bees have remained in this " cluster " state overnight,

but usually they are lost unless they are collected inside of three hours. The swarm consists of a large number of adult bees, workers, and drones, and usually a single queen.

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FIGURE 54. — HONEY-BEES CLUSTERING AT SWARMING TIME.

Various devices against swarming have been invented but the most effective is to clip the wings of the queen in order that she may be kept at home because the other bees usually follow her. This is done after the queen has taken

her "wedding-flight." Her wings are clipped close to the body. The bees that then swarm soon come back and are easily controlled. While the bees are still in the air, a clean, empty hive is placed where the old one was. Bee-keepers, during the swarming period, always have a number of empty hives in position ready for the swarm to occupy.

FIGURE 55. — CAPTURING A SWARM.

The returning bees enter the new hive in search of the queen. As they are rushing in, the queen with clipped wings is released and she, in turn, joins the procession and enters with the others. Having found the queen and plenty of room, the colony is usually content to remain. Sometimes swarming becomes a mania with certain colonies and it is difficult to get them to settle down contentedly in a hive and make honey. Runaway swarms have to be watched with great patience. Bees that have been raised for many bee generations in man-made hives (Figure 56) sometimes leave suddenly and seek out a hollow tree in the forests.

The length of the bee's life varies. The drones are usually killed at the end of their first season. Queens live for five or six or even ten years. Workers live three or four weeks in the working season and several months in the fall or winter.

The honey and wax produced annually in the United States are valued at $25,000,000.

90. Adaptation Shown in the Honey-bee. — The honey-bee offers a fine example of adaptation. The tongue is adapted to getting nectar from certain flowers like apple blossoms, lindens, white clover, and sweet clover. It is too short to get nectar from red clover blossoms. The mandibles

FIGURE 56. — MODEL APIARY.

are adapted to gathering propolis from buds, also for kneading the wax and for polishing surfaces. The wings are adaptations for the particular life of the honey-bee. In the first place they are small, and are not likely to be injured when the bees are packed closely together as in swarm clusters. Then, to compensate for the small size, they are vibrated with great rapidity to carry the bees through the air with a load of nectar and pollen. Sometimes they vibrate 440 times per second.

The rear pair of legs is adapted not to jumping, as in a grasshopper, but for carrying loads of pollen and propolis. These legs are flat and thin and provided with bristles to keep the load from sliding off.

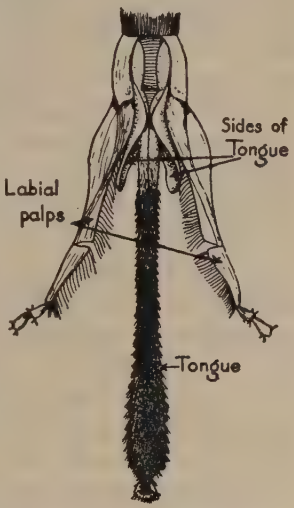

FIGURE 57. — TONGUE OF HONEY-BEE.
Notice the numerous hairs of the tongue and palps.

91. Ants. — Many interesting facts about the honey-bees are well known, but less attention has been paid to the ants, although these seem to be even more wonderful insects.

They live in large families with many workers, and a number of queens and males. Some have, in addition, soldiers with strong mouth parts (mandibles) to do the fighting for the colony.

92. Interesting Behavior. — Ants act more like human beings than perhaps any other animal. Here are some of the things they do.

1. They build beaten roads with tunnels under brushpiles.
2. They keep plant lice for the sweet fluid they exude which suggests the keeping of cattle by man.

FIGURE 58. — WORKER HONEY-BEE LADEN WITH POLLEN.

3. They carry these plant lice into their tunnels and care for them over the winter season. In the spring they carry them out and place them on food plants.
4. If a nest is attacked by enemies, the soldiers rush around and stroke the workers with their antennæ. This seems to inform them of the attack and they hurry to the rescue.

5. They wrestle and play and sometimes carry one another around. It looks like a football game.

6. They have battles with other colonies. Before a battle starts they send out scouts. They await the return of the scouts before they begin the battle.

7. When one colony subdues another in battle, the victors take home the larvæ and pupæ of the vanquished and bring them up to be slaves. The slaves seem to be loyal to their conquerors and to take great interest in the welfare of the victorious colony.

8. Among certain kinds of ants the slaveholders have depended so long on the slaves that they are unable to build nests or even feed themselves. If the slaves are taken away, the slaveholders starve. The slaveholders are able to fight, however, to get more slaves.

93. Life History of the Ant. — In most ant colonies there are several queens. Unlike the honey-bees, several queens live in harmony in an ant colony. The ant eggs are so small that they are scarcely visible to the unaided eye. The legless larvæ hatch in a few days, being full grown in about two weeks. Pupation lasts about two weeks. The cocoons are the white objects which are commonly called " ant-eggs." The adults guard these cocoons which contain the pupæ, carrying them away to places of safety when the colony is disturbed. Sometimes the adult workers remove them to warmer quarters.

The males and females have wings while the workers are wingless.

OUTLINE

Moths and butterflies
  Monarch butterfly
    Life history
    Complete metamorphosis
  Enemies
    Parasites
    Birds
Bees
  The Colony
    Workers

Queen
Eggs
Development
Swarming
Adaptations
Ants
Interesting behavior
Eight habits like men
Life history

SUMMARY

Among the commonest and most interesting insects are monarch butterflies, bees, and ants. The life history of the monarch butterfly gives us a good illustration of complete metamorphosis. The chief enemies of this moth as of most insects are parasites and the birds which prey upon them.

Of all insects the bees are among the most valuable to man. They live in colonies under the command of a queen who alone lays the eggs from which new bees are hatched. Fertilized eggs can result in queens or workers according to the food the workers give it. When a colony becomes crowded bees usually swarm. They are remarkably well adapted for making honey.

Ants are more like people in their behavior than any other insects. They build roads, keep other insects for food, have soldiers and slaves, make war on each other, and sometimes even seem to play games.

QUESTIONS

What are some of the most harmful moths? Some of the most beautiful? Describe the life history of the monarch butterfly. What does it illustrate? What are two of the chief enemies of moths? What three kinds of honey-bees are there? How does each come into being? Give the life history of a bee from egg to fully developed worker. Why do bees swarm? How is a swarm handled by the bee-keeper? What adaptations has the bee? In what different ways do ants act like human beings? Do they have queens? Workers? Describe the life history of the ant.

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CHAPTER IX

THE CRAB FAMILY AND HOW THEY LIVE

You cannot make a crab walk straight.
— ARISTOPHANES,

94. Crustaceans. — The *Crustaceans* (krŭs-tā′shŭns : Latin, *crusta*, crust) are so called because of their hard outer covering. This family is closely related to the insects. The similarity is most easily seen in the external skeleton and the several hinge-joints in the legs which they have in common with insects. Crabs, lobsters, and shrimps are among the most familiar crustaceans.

FIGURE 59. — CRAYFISH, SHOWING EGGS.

The body consists of a limited number of segments, each of which usually bears a pair of jointed appendages. The appendages are variously modified; some aid in swimming, others in securing food, and others are used in walking. On the walking legs are located most of the gills that aid in respiration. The others are on the thorax.

The jointed appendage is the distinctive characteristic of the group to which crabs and lobsters belong. For this reason this group is given the technical name *Arthropoda* (är-throp'o-da: Greek, *arthron*, joint; *pod*, root of *pous*, foot).

95. Crayfish. — Those who live inland can study the common crayfish or "crab" as a typical crustacean, while those who are near the seashore can observe the lobster. They are so similar that a description of either one will serve to indicate the chief characteristics of both.

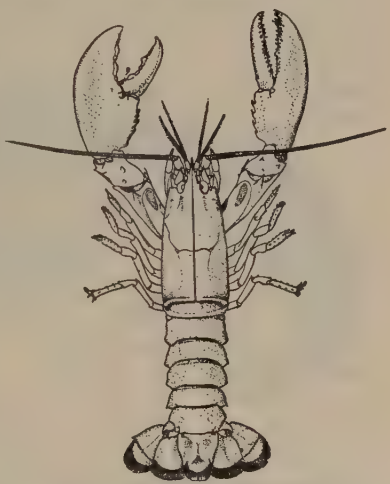

FIGURE 60. — MOULTED EXOSKELETON OF LOBSTER.

One can tell just what kind of an animal this is simply by studying this cast-off shell.

96. Body. — The body is covered with a hard outside skeleton called an *exoskeleton* (from *ex*, out). In animals like frogs or fishes the skeleton is within the body and the flesh is on the outside, so it is customary to refer to such a skeleton as an *endoskeleton* (from *endo*, inside).

The lime which composes the skeleton is furnished by the food the crayfish eats. As this substance is necessary to its growth, we find the crayfish living only in streams where lime may be secured. The exoskeleton is mainly for the protection of the crayfish against the animals that eat it. The color in the shell also helps to protect it because this color usually resembles that of its natural surroundings.

The crayfish is divided into two regions, the *head-thorax* region and the *abdomen*. The segments of the abdomen are

clearly defined, but those of the head-thorax, technically termed the *cephalothorax*, are so fused that they can be made out only with difficulty.

Molting. — An interesting feature in the study of the crayfish is the shedding of the external skeleton. As it is covered by a firm exoskeleton it must get rid of this occasionally, in order to grow. Molting, in the case of the crayfish, is a serious and dangerous operation, as it is followed

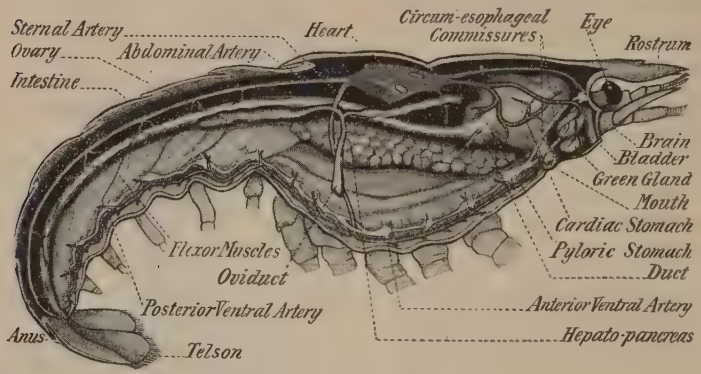

FIGURE 61. — BODY OF CRAYFISH.

by a period during which the crayfish is without means of offense or defense. The crayfish usually hides until a new exoskeleton is partially formed. In the molting process the covering of the eyes and part of the lining of the digestive tract, as well as the whole exoskeleton, are shed. The crayfish molts every year of its life and several times during the first year (Figure 60).

The last abdominal segment and the appendages next to the last are broad and form a tail fin (uropod).

97. Appendages. — The crayfish has nineteen pairs of appendages located on the lower or ventral surface of the body. They are used for swimming, walking, protection, capturing prey, crushing food, and as special sense organs.

The swimming appendages on the abdomen are very simple, two-parted feet, known as *swimmerets* (Figure 62). The last appendage on the abdomen is much enlarged, with each part greatly flattened. (See *uropod* in Figure 62.) This flattened foot is an adaptation that helps the crayfish in swimming backwards.

On the thorax region, the feet have changed into large, many-jointed structures that are strong enough to support the body in walking. (See walking leg, Figure 62.) The first walking leg is much larger than any of the others and terminates in a strong pincer (*chela*, Figure 62). The chela is used in fighting, in defense, and in capturing food. On the basal joints of these walking legs are found gills that absorb oxygen from the water.

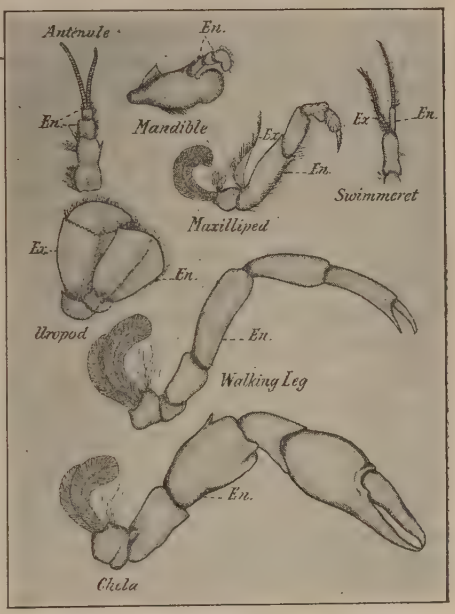

FIGURE 62. — APPENDAGES OF CRAYFISH.

Just in front of the walking legs are located six pairs of appendages that assist in bringing food to the mouth after it has been crushed and torn to pieces. There are three pairs of maxillipeds, two pairs of maxillæ, and one pair of mandibles (Figure 62).

The mandible is short and hard and has a broad surface on the end. When the two mandibles come together, their

action is mainly to crush food but this broad surface is also rough so that they have a grinding action.

The two pairs of appendages just back of the mandible are very thin, almost leaf-like, and covered with sensory hairs. These hairs are supplied with nerves and are classified as taste and touch hairs. The second maxilla supports a special fold, scoop-shaped, which extends into the gill chamber. Its function is to help in respiratory movements by keeping the water circulating in the gill chamber. The water is drawn in from the back edge of the gill chamber and passes out near the mouth. We may show this by placing a few drops of red ink at the back edge of the gill chamber of a live crayfish, being sure to have the water cover its back.

The three remaining pairs (maxillipeds, Figure 62) are similar to the abdominal appendages with the parts marked " en " and " ex " much enlarged.

The crayfish has two pairs of antennæ that are used for feeling and possibly tasting. Special students of the sense organs in the crayfish and similar animals doubt very much if the word " taste " is the best one to use in describing the responses which a crayfish gives when a drop of meat juice is placed in the water near the mouth parts or an antenna and the crayfish begins to move the mouth parts as it does when eating.

In the basal joint of the small antennæ is located a sac which is covered with a plate. The edge of this plate is furnished with hairs. The sac communicates with the water. It is the " ear " of the crayfish but is more correctly termed the " balancing organ." The crayfish does not hear with this organ but is unable to swim naturally when the " ears " are removed.

In Figure 62 the parts of the appendages are marked " en " and " ex " to indicate just which one becomes enlarged or reduced in comparison with the other. There is no better illustration in zoölogy of the extent of adaption in the same

structure than that shown in this study of the appendages of the crayfish.

It seems very strange to include the eye of the crayfish in the list of appendages. Some scientists insist that it is a very much reduced appendage while others reject this interpretation. This is the reason that the number of appendages is sometimes given as twenty.

The eye is on the end of a movable stalk. It is compound because it consists of more than 2,500 distinct parts. It is hardly correct to say that the compound eyes represent 2,500 simple eyes fused into one but so far as the action of each is concerned this might be said. For each one " sees " only the object directly in front of it. Thus the crayfish does not have a continuous complete picture of an object as we do but rather numerous partial and incomplete views that resemble a mosaic floor. Such vision is hence termed *mosaic vision.*

LABORATORY STUDY ON THE APPENDAGES

Examine more fully than in the above and report the work of each pair of appendages. Compare one of the abdominal appendages with those used in walking and feeling. What is the work of the large pincers? How many fin-like appendages are found in the mouth region? Notice that one of the mouth appendages has a flat part that extends in front of the gills. This part of the appendage is called the gill scoop or bailer. Describe how the appendages show at least three useful adaptations in the life of the crayfish.

98. Necessity of All Life Processes. — As in the case of the grasshopper and other insects we have studied, the life processes of the crayfish are interesting enough to be taken up in some detail.

Food and Food-getting. — The crayfish feeds on plants and animals, living and dead. One of the simple water plants, *Chara* (kā'ra), furnishes the crayfish with lime for its skeletons. Shells of snails and their own shed skins also help to supply lime. Crayfish seize food with their pincers

and move it towards the mouth. Small food particles are also carried towards the mouth by currents of water produced by the mouth parts and the abdominal appendages. Particles of food are torn loose by the teeth or mandibles.

Digestive System.—The mouth of the crayfish is just back of the mandibles, and connects with the stomach by a short esophagus. The stomach is divided into front and back parts. The front part possesses a grinding structure known as the

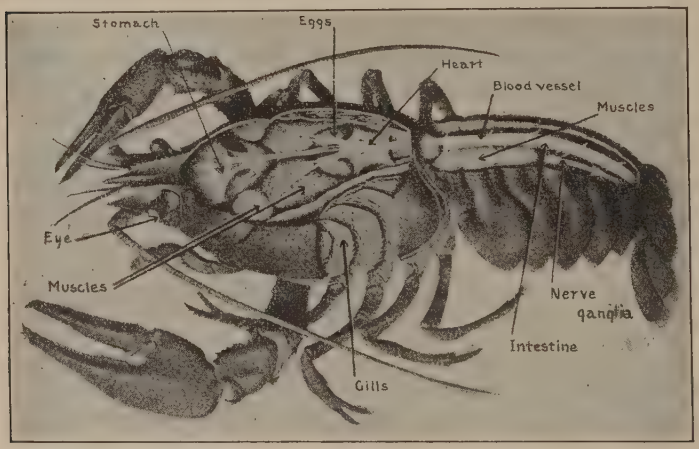

FIGURE 63.—ORGANS OF CRAYFISH.

Note that the gills are outside of the body. In the posterior part of the abdomen, the muscles have been removed to show the nerve ganglia which extend the entire length of the body.

gastric mill, which serves to shred and crush the food and make it ready for digestion in the back part. The liver, or digestive gland, pours a fluid into the stomach, which prepares the food for absorption by the walls of the stomach and intestine. The intestine begins at the back end of the stomach and extends to the last segment.

Respiration.—Crayfish obtain oxygen from the water by means of gills which are well covered by the overhanging

skeleton of the head-thorax region, but are really outside of the body. Most of the gills are plume-like in shape and are attached to the appendages, but some of them are attached to the thorax. Water is made to circulate through the gill chamber by means of the gill scoop or bailer. The finely branched gill affords a large amount of surface for the absorption of oxygen.

Excretion. — The organs for excretion of waste are the *green glands* that are found at the base of the antennæ. Blood going to these glands loses some of the waste which it has gained in its course through the body. The method of purification of the blood in these glands is much the same as in the kidneys of the higher animals.

Circulatory System. — The crayfish has a well-developed heart from which extend several arteries that carry blood to the various parts of the body. The blood returns to the heart through veins and through several irregular ducts called *sinuses* (sī′nŭs-ĕs). As the blood flows through the body it loses oxygen and receives carbon dioxide. Fresh oxygen is absorbed by means of the gills, which, at the same time, pass off carbon dioxide from the blood into the water.

The Nervous System. — In the crayfish this is made up of a brain, ventral nerve chain, and many nerves. The eyes are borne on a pair of short movable stalks. The special senses are well developed, and the sense of taste is keener than that of most lower animals.

99. Life History. — The sexes are distinct. The males may be distinguished from the females by the larger tubular appendages on the first and second segments of the abdomen. The eggs of the female become glued to the hairs of the swimmerets where they remain until hatched. In fact, young crayfish remain for about a fortnight after hatching grasping the hairs with their pincers. During this time they have fed for the most part on the yolk that was in the

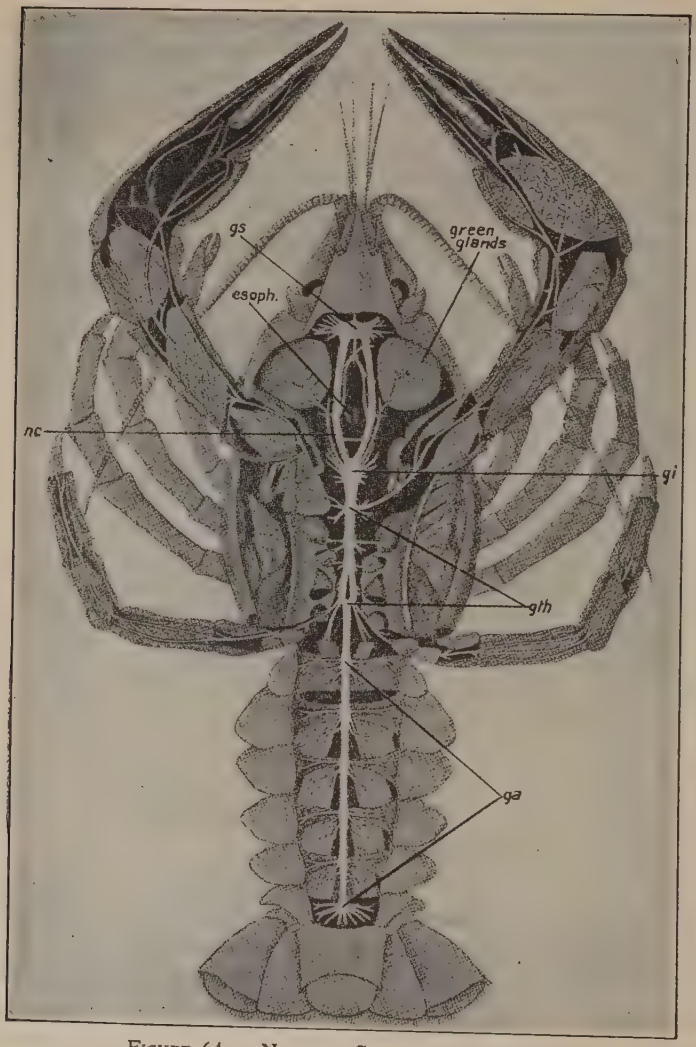

FIGURE 64. — NERVOUS SYSTEM OF CRAYFISH.

esoph, esophagus; *gs*, "brain"; *gi*, *gth*, ventral ganglia of thorax; *ga*, abdominal ganglia; *nc*, nerve collar.

egg stalks and case. The young now begin to look like the parent.

The common crayfish breeds annually and those that hatch from the eggs laid in the spring may, in turn, lay eggs the following spring.

LABORATORY STUDY

Place several crayfish in jars or aquaria and observe their behavior. Fill out the following report:

Do they Move the Antennæ?	Do they Walk Forward?	Do they Walk Backward?	Do they Use Tail Fin?	Do they Move Eyes?	What Organs Make a Current in Water?

100. Economic Importance to Man. — Shrimps, lobsters, and crabs are crustaceans of much economic importance, because of their food value. The trade in these animals amounts to millions of dollars each year. In order that these important food animals may not become exterminated by careless and excessive fishing, the state and national governments have attempted to control the numbers taken.

FIGURE 65. — SOFT-SHELLED CRAB USED FOR FOOD.

The common crayfish has been used for centuries for food in Europe, while in France crayfish farming to increase the supply has been successfully practiced for some time. For many years crayfish have found their way to the markets of American cities which possess a large foreign population. Crayfish

may also be harmful. They often burrow and may cause serious damage to dams and levees. At one time they were very destructive to the cotton planter by burrowing in the soil and feeding on the roots of the cotton plant.

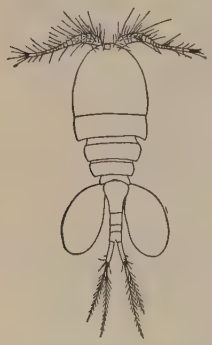

FIGURE 66. — CYCLOPS.

As a source of food the American lobster is widely used, as its body contains a large supply of meat. White men caught lobsters in Massachusetts Bay early in the seventeenth century. In 1630 the English settlers were well acquainted with lobsters as food. From that time until now they have been regarded as a delicacy. They are in such great demand that the states of the northern Atlantic coast have placed a size regulation to prevent small lobsters from being legally taken.

The total value of the lobster fisheries in the United States is over a million dollars. About three fifths of the catch comes from the coast of Maine. The lobster fisheries of Canada are also important, ranking next to the codfish and salmon.

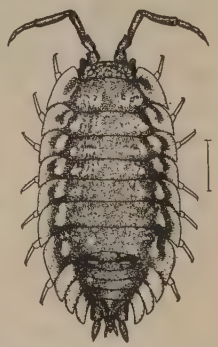

FIGURE 67. — PILL-BUG
One of the common crustaceans found under boards.

In order to keep up the supply of lobsters, state and national governments have established hatcheries where the eggs are hatched artificially. During this process the eggs are protected from the animals that naturally feed on them. After the young lobsters are hatched, they are placed in the ocean. Lobsters come to maturity when about ten and one-half inches long. Young lobsters lay about 10,000 eggs, while an older one may have over 90,000 eggs attached to its body.

Shrimps and the blue crab (Figure 65), are also an important food for man, while the minute crustaceans are an important food for fish and whales.

101. Other Crustaceans. — Crustaceans of less economic importance than shrimps, crabs, and lobsters are the barnacles which cling to rocks, wharves, and ships; the hermit crabs that live in the shells of *mollusks* (mol′lŭsks); and the smaller fresh-water crustaceans such as the *Cyclops* (sī′klŏps), *Daphnia* (dăf′nĭ-a), and *Cypris* (sī′prĭs), which are barely visible to the unaided eye.

Photograph by J. H. Comstock.

FIGURE 68. — SPIDER.

102. Arachnids. — The spiders, scorpions (skôr′-pĭ-ŭns), ticks, and mites are arthropods that are grouped together under the name *Arachnida* (ă-răk′nĭ-da: Greek, *arachne*, spider). The spiders and scorpions have eight walking appendages. The forward pincers of the scorpions are mouth parts, and not walking appendages. The harvestman (*daddy-long-legs*) is a harmless arachnid which does good by destroying injurious insects. Spiders catch insects either by pouncing upon them or by entangling them in their webs. Scorpions sting severely, but the wound, although painful, is rarely fatal. Some ticks and mites are parasitic on man and beast, and may transmit dangerous diseases such as the Texas fever of cattle.

103. Myriapods. — Another group of arthropods is the *Myriapoda* (mĭr-ĭ-ă′pō-dä: Greek, *myrioi*, ten thousand;

pous, foot, root, *pod*), a group which includes animals of many legs such as the centipedes (sĕn′tĭ-pēdz) and "thousand-legged worms." Centipedes are provided with poison glands, hence their bite is fatal to some of the smaller animals and painful to man. The thousand-legged worms or millipedes are harmless.

With permission of Nature Magazine.

FIGURE 69. — WEB OF SPIDER.

104. Importance of the Mollusks to Man. — There is another group of animals, the mollusks, that have had an intimate relation to man from his earliest appearance in this country. Huge piles of shells of clams and oysters remain as records of his earliest feast celebrations. They were made before he had learned to write. From this ancient time until today, when the oyster industry is valued at $15,000,000 and the clam industry at $1,000,000, these animals have held an important economic place in the life of man.

These animals differ from the crustaceans in having an unsegmented body which is usually covered by an exoskeleton. This external skeleton consists of a single piece in snails and of two parts or valves in clams. When the clam moves naturally, the hinge between the two valves is uppermost

while the opening between the valves allows the foot to be extended into the mud (Figure 71). The foot is a thick, muscular mass, not at all foot-like in appearance, but it enables the clam to move slowly and at an even rate.

The great majority of buttons used by mankind to-day are made from the shells of clams and mussels. The Pearl Button Industry in the United States has developed until in 1914 the manufacturing plants were valued at $4,900,000. In 1921 over $700,000 worth of pearl buttons were exported. Only the shell is used, the flesh of the clam being sold as fertilizer, or used for poultry food.

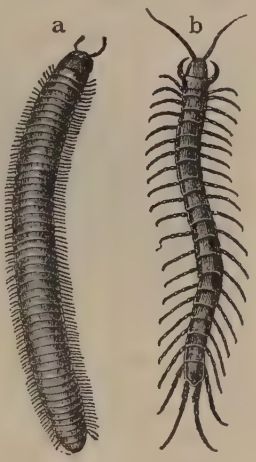

FIGURE 70. — *a*, MILLIPEDE; *b*, CENTIPEDE.

A few years ago this industry promised to fail because the life history of the fresh-water clams was not understood. Two well-known biologists were employed by the United States Government to work out the breeding habits and methods of hatching and conditions of growth. They found that the newly hatched clam (Figure 73) consists of two parts with teeth on the edge. This young clam swims about opening and closing what looks like an animated pincer. As it opens and closes it may come in contact with either the fins or gills of a fish. Here it remains for some time,

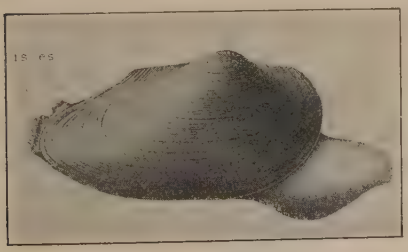

FIGURE 71. — CLAM, SHOWING FOOT.

Water enters through i.s., inhalent siphon, and leaves the body of the clam through e.s., exhalent siphon.

finally dropping off into the water, still a very small clam. If it does not attach itself to a fish, it dies. Just as soon as these facts in the life history of clams were well understood, it was possible to formulate regulations governing the time

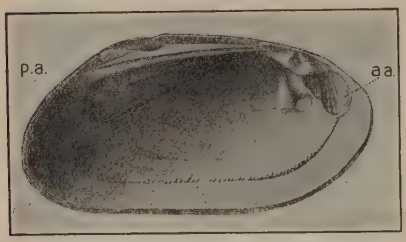

FIGURE 72. — INSIDE OF CLAM SHELL.

Showing anterior (a.a) and posterior (p.a.) adductor muscles. Buttons are made from this shell, which is the external skeleton of the clam.

FIGURE 73. — EMBRYO OF CLAM.

At this stage it becomes attached to the gills or fins of a fish. Here it remains for some weeks, gradually transforming into a clam.

when clams could be properly taken and the kinds of fish best suited to their development.

OUTLINE

- Crustaceans
  - Crayfish
    - Body
      - Skeleton
      - Cephalothorax
      - Abdomen
    - Appendages
      - Legs
        - Swimmerets
        - Walking
      - Others
        - Maxillæ
        - Mandibles
        - Antennae
        - Eye-stalk
    - Life processes
      - Life history
      - Molting
      - Economic importance
  - Arachnids
    - Spiders
    - Scorpions
    - Ticks
    - Daddy-long-legs
  - Myriapods
    - Centipedes
    - Millipedes
  - Mollusks
    - Clams
    - Oysters
    - Mussels

SUMMARY

The crustaceans are so called because of their hard outer shell. Of the division called *Arthropoda*, crabs, lobsters, and shrimps are the best know varieties. All three are of economic importance to man as food. They have a body consisting of cephalothorax and abdomen, while their many appendages include legs, mandibles, antennae, and others. They have the same life processes as all animals and an interesting life history. They molt in order to allow for growth.

The mollusks and arachnids do not belong to the crustaceans. The former include clams, lobsters, and mussels, while to the latter division belong the spiders, scorpions, and ticks.

QUESTIONS

With what crustaceans are you most familiar? Describe the crayfish. How many parts has its body? What kind of appendages does it have? How does it take food? Respire? Excrete? Describe its circulatory and nervous systems. Where do the eggs remain until hatched? What is molting? How are crabs and lobsters important to man?

What are mollusks? How many kinds do you know? Of what use are they to man? Name some crustaceans. To what group do spiders belong? What is their value to man? Which of the myriapods are harmful and which harmless?

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CHAPTER X

A SIMPLE VERTEBRATE, THE FISH

O scaly, slippery, wet, swift, staring wights,
What is't ye do? what life lead?

— Leigh Hunt

105. Vertebrates. — All the animals which we have studied so far are called *Invertebrates*, because they have no backbone. We are now to study the *Vertebrates*, animals with a backbone, such as fishes, frogs, snakes, birds, and mammals.

The most conspicuous characteristic of vertebrates is the presence of a backbone. The formation of the backbone is always preceded by the growth of an embryonic group of cells that do the work of a skeleton. This embryonic group of cells forms a structure which is called the *notochord* (nō′tō-kôrd : Greek, *notos*, back; *chorda*, cord). In all the true vertebrates (such as fishes, frogs, etc.), the notochord is gradually absorbed and the backbone takes its place, but between the vertebræ it remains as cushions. But in the fish-like vertebrate called *Amphioxus* (ăm-fĭ-ŏks′ŭs), the notochord persists and there is never a true backbone. The notochord is always found above the food tube and below the spinal cord.

Another characteristic common to all vertebrates is the presence of gill-slits. In the fishes these are external openings on each side of the neck that allow the water to pass over the gills. Such structures are of use only to aquatic

animals, and yet all vertebrates have them at some time in their development.

The skeleton of most vertebrates is composed of bone. There are usually two pairs of appendages (legs, wings, or fins) attached to the body at the shoulder and hip. Here special bones join the limb to the body. The bones in the shoulder are known as the *pectoral* (pĕk′tŏ-ral) girdle; while those in the hip are termed the *pelvic* (pĕl′vĭk) girdle. In the snakes, only traces of legs are found.

FIGURE 74. — PERCH, AN IMPORTANT FOOD-FISH COMMON IN NEARLY ALL FRESHWATER PONDS.

A further distinguishing feature of all vertebrates is the well-developed nervous system, with its large brain. The sense organs, eyes, ears, and the like, are also better developed than in any of the invertebrates.

Oxygen is obtained by external or internal gills in most aquatic animals and by lungs in all other vertebrates. In many vertebrates the skin is an active agent in the interchange of oxygen and carbon dioxide and particularly in those animals which have a thin, moist skin like frogs.

106. Fishes. — The fishes are vertebrates, that is, they have a notochord which, as they develop, gives place to a

vertebral column. There are four large divisions of fishes: (1) the lampreys (lăm′prĭz) and their relatives, (2) the sharks and their kin, (3) the bony fishes, and (4) the small

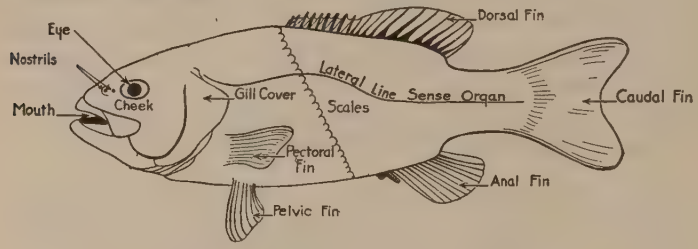


FIGURE 75. — EXTERNAL PARTS OF FISH.

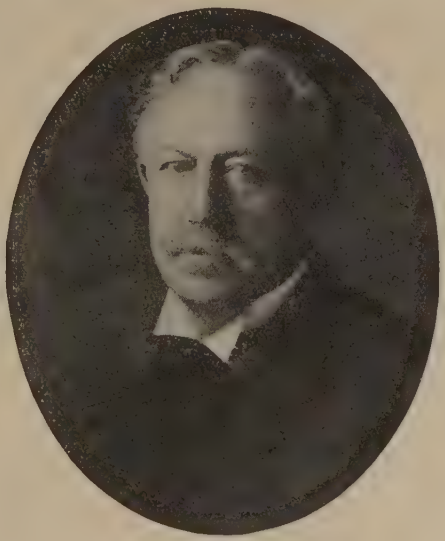
group of fishes with lungs. The bony fishes constitute the most important group in numbers and economic importance. This group includes the salmon (săm′ŭn), trout, bass, whitefish, pike, shad, menhaden (mĕn-ha′d'n), cod, mackerel, herring, sardine, etc. Typical bony fishes are the goldfish, perch, and sunfish (Figures 74 and 77).

107. External Parts of a Fish. — The external parts of a fish consist of a well-marked head attached directly to the trunk; a trunk region, the largest part of the body; and a tail region which is sometimes as long as the trunk.

FIGURE 76. — SCALES OF FISH.

In a bony fish the eyes are well-developed and the mouth is at the front end of the head. The jaw bones, bearing many small, needle-like teeth, are not firmly attached to the skull. The side of the head next to the trunk is protected by a piece of bone that covers the gills (gill cover or *operculum*, ŏ-per′ku-lŭm).

The trunk bears a number of appendages called *fins*. Each fin is furnished with several bony fin-rays covered by a thin fold of skin. On the shoulder and hip



David Starr Jordan was born in Gainesville, N. Y., 1851, and is still living. He took his master's degree from Cornell in 1872, his medical degree from Indiana Medical College in 1875, and his doctor of philosophy degree from Butler University in 1878. Since then he has received the honorary degree of doctor of laws from four of the leading American Universities.

In addition to teaching biology for many years, he has written numerous technical and popular books on various phases of biology. From 1885 to 1913 he was President first of Indiana University and then of Leland Stanford University. During all this time he continued his scientific studies. He is one of the most eminent authorities on fishes in the United States. Dr. Jordan's life and attainments are striking examples of what an American boy can accomplish by his own efforts and individuality.

regions of the trunk, the fins occur in pairs and are called the pectoral and pelvic fins. Several fins are found that are not in pairs. These are the median fins of the trunk.

The caudal or posterior region of the fish ends in a large median fin. The tail region is chiefly important in locomotion, but the fins also help in balancing and steering.

Scales cover the trunk and tail, each one overlapping the next like the shingles of a house. The skin is full of mucous glands that keep the fish covered with slime. Both the slime and the scales protect the fish (Figure 76).

LABORATORY STUDY

Study living fish, such as goldfish or perch. Place one or two in an aquarium and observe their behavior. Fill out the report below.

Number of Fins	Number of Paired Fins	Number of Unpaired Fins	Which are Used to			Do the Eyes Move?
			Advance?	Stop?	Balance?	

Note the shape and relative position of the head, trunk, and tail region. The gills are covered by a bony shield, the operculum. What is its size and how attached? Where are the eyes located? Do they move? Can the eyes be closed? How is the body covered? Of what use is this covering to the fish?

108. Locomotion. — The bodies of such fishes as are shown in Figures 74 and 77 are adapted to swimming. The tapering head offers but little resistance to the water and the general spindle-shape of the whole body enables it to move easily when completely surrounded by water. Notwithstanding that there are paired fins which are similarly placed to the paired legs of a frog or dog, these fins are not important in giving speed to the fish's movements. They

act as brakes when the fish desires to stop, the brake being applied by simply straightening out these paired fins at right angles to the body. The median fins on the back and lower surface of the body keep the fish from tipping over and are chiefly for balancing, the paired fins also assisting in this process. The tail of a fish is supplied with a large terminal

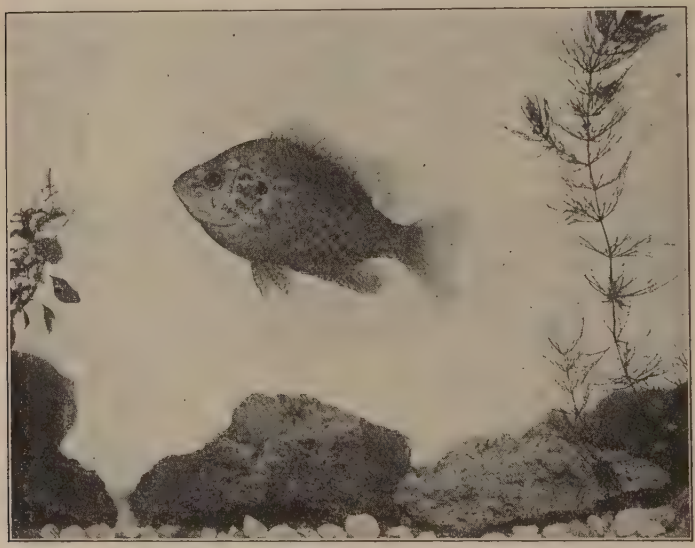


FIGURE 77. — SUNFISH OR PUMPKINSEED.
The one usually caught by the small boy fisherman.

fin. This fin and the tail which is often one third of the entire length of the body of rapidly swimming fish, is the chief organ of locomotion. Movement is produced by a rapid sidewise motion of the tail.

109. Food-taking. — Fishes eat insects, worms, crayfish, snails, and other fish. The teeth of fish serve to seize, tear, and hold food. None of the fish have teeth which are adapted to chewing the food, as is the case among the higher vertebrates, like the dog, horse, and man.

The insects which form the principal diet of many fish are so well known that anglers select special ones for bait. However, not all water insects are eaten by fish. Contrary to the usual order of things, there are insects that kill fish. The fish-killing insects spend all of their time in the

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FIGURE 78. — FISH-EATING INSECT.

water except when migrating from pond to pond or during the mating period. They conceal themselves beneath stones or lie partly buried in the mud. From these places of hiding, they dart out and seize their victims with their jaws or claws. The water-tiger, a larva of one of the water beetles, is equipped with curved, sharp, hollow jaws with which it

pierces its prey and sucks the juices of the body. The largest and most destructive of these fish-killing insects is a true bug (Figure 78) which grasps the fish with its curved fore-legs, plunges its large, sharp beak deep into the fish and then slowly sucks its blood. These and other insects feed on the eggs of fish so that, when artificially hatching fish, man has to protect the eggs and young fish from insects which we used to think were only a source of food to the growing fish.

In fishes which eat minute animals and plants the four pairs of gill arches are adapted to support many sharp-pointed projections on the inside. These act as strainers and gather quantities of this small food as the water passes over the gills. These projections are called *gill rakers* (Figure 79). Their development seems to vary in proportion as they are needed for service. Fishes that feed on crayfish and on small fish have no use for gill rakers or strainers and accordingly their gill rakers are undeveloped.

The food captured by the teeth of the fish or caught in the gill strainers passes at once into a short esophagus which expands into the thick-walled stomach. Here the various plants and animals that have been swallowed undergo partial digestion, the remainder of the process being completed in the intestines. The dissolved foods are absorbed through the walls of the stomach and intestine by osmosis and pass into the blood. The main parts of the digestive system and their adaptation to digestion are the same as in all the higher vertebrates.

110. Gills and Respiration. — Water is taken in through the mouth and passes out through two openings, one on each side of the neck. In each opening four or five gills are found. The gills are a series of vascular arches made up of numerous, small, very short, fleshy threads or filaments (Figure 79). Into each filament a blood vessel penetrates and here the blood throws off carbon dioxide and takes

oxygen from the water by osmosis just as the blood of the crayfish does. The thin-walled gill filaments are adapted to respiration in the water. The water is drawn into the mouth and forced out over the gills in much the same way as water is pumped from a well. When a fish opens its mouth, the water rushes in. As the mouth is closed, the

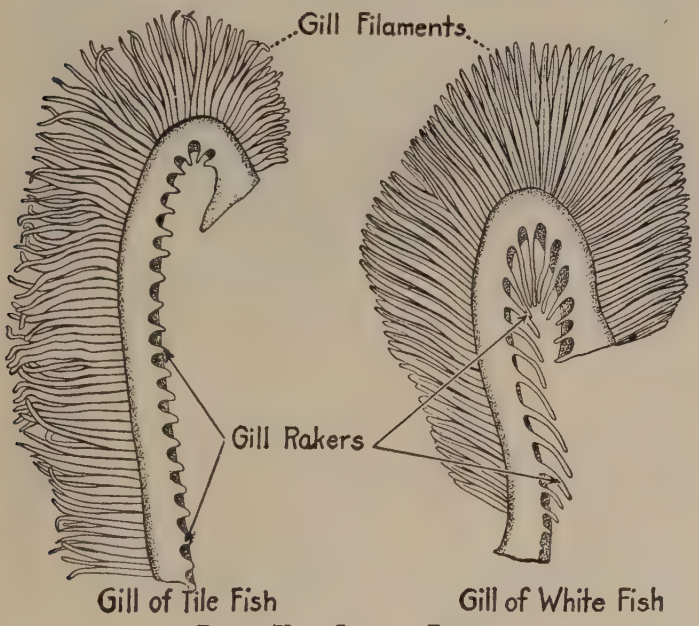

FIGURE 79. — GILLS OF FISHES.

floor of the mouth and throat is raised slightly, pushing the water against the side of the neck and through the gill opening. The mouth is thus emptied of water so that when it is opened again more water flows in.

111. Circulation. — The blood of fishes is carried in well-defined blood vessels and a heart of two chambers. The blood is sent from the heart to the gills, where it is purified of carbon dioxide and receives oxygen. It is then carried

by means of arteries to other parts of the body, where the oxygen in turn is given up and carbon dioxide is received. The blood from the gills and other parts of the body is returned to the heart through veins. Because the temperature of the blood of fishes is lower than that of man and changes with the seasons, they are called cold-blooded animals.

112. Excretion. — The waste produced in all parts of the body as a result of the use of oxygen in the process of oxidation is in the form of a gas known as carbon dioxide. This gas is carried in the blood to the gills where it passes by osmosis through the thin walls of the gill filaments into the water. In addition to oxidation, there are other vital processes taking place in all the cells of the body of the fish. These vital processes produce waste substances that exist in the form of liquids which are gathered up by the small blood vessels and carried to the kidneys of the fish. Here these liquid wastes are extracted from the blood and are cast off from the body.

113. Nervous System. — The nervous system of a fish consists of a spinal cord and a well-developed brain. There is no structure in the nervous system of a crayfish that can be compared to the brain of a fish. Many nerves connect the brain and spinal cord with all parts of the body and these nerves belong to the nervous system. Associated with better development of the brain are special sense organs.

Special Senses. — The eye is well developed. It is globular and projecting, and it is believed to be near-sighted. The organs of smell are usually located in the nasal cavity. In the bullhead, they are found in the feelers, on the head, and even in the skin of the tail. The ear is under the skin, and there is no external opening. As water conducts sound vibrations more readily than air, no device for gathering sound waves is necessary.

114. Reproduction. — The sexes of fish are distinct. At certain seasons many fish migrate upstream to lay their eggs (to "spawn"). Eggs are laid in large numbers by

FIGURE 80. — EGGS OF THE LAND-LOCKED SALMON.

the females, and in the same locality sperm cells are discharged into the water by the males. The sperms unite with the eggs. The fertilized eggs hatch after thirty or forty days, or longer, depending on the kind of fish and the temperature of the water. The yolk of the eggs is

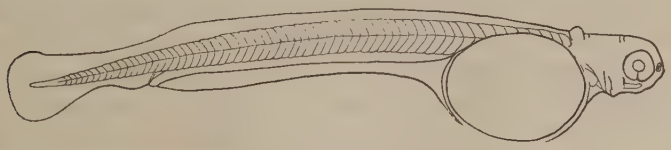

FIGURE 81. — YOUNG FISH JUST AT THE HATCHING STAGE.

The large mass under the neck is the yolk or food used by the young fish before it is able to capture its own food. Note that there are no fins and that the gills are not well developed.

attached to the young fishes for many days after they are able to swim, and supplies all the food they need during this time (Figure 81).

The spawning habits of fish must be understood thoroughly if they are to be raised artificially, as is done in the many fish hatcheries. Most states have scientific game laws which protect the fish during their egg-laying period when they are easily caught and when the destruction of even a few fish means the loss of thousands of eggs.

Spawning habits vary greatly. Some fish, like the salmon, make long journeys from the sea to the head waters of rivers and streams to deposit their eggs. The Columbia River is famous for the number of salmon which spawn there. Other fish, like shad, go up a river only a short distance to lay their eggs. Many shad, for instance, go up the Hudson River in New York State.

FIGURE 82. — YOUNG FISH SEVENTEEN DAYS AFTER HATCHING.

It has absorbed the large mass of food and the fins and gills are large enough to be used by the young fish which must capture its own food from now on.

115. Care of Young. — Some fish, like the sticklebacks, build nests of sticks and leaves in which the eggs are placed and guarded. Bass and sunfish make a circular depression several feet in diameter near the shore and lay their eggs on these so-called "beds." These beds are guarded zealously by the males, who drive off or carry away crayfish and small fish which feed upon such eggs. In former times men sought for these "beds" and by dropping a baited hook caught the bass while defending their eggs. Fortunately this practice is now illegal. Generally, adult fish pay no attention to their young and in many cases they devour young of their own kind as quickly as fish of other sorts.

116. Life History of the Eel. — This well-known fish of the inland streams and lakes has had so many stories and myths in connection with its development that much effort

has been made to learn the facts. Eels migrate downstream to the larger rivers and eventually to the ocean in the fall of the year. Here in the region of mud banks the females lay their eggs in great numbers and the sperm cells of the males fertilize them. In some cases the females lay as many as 10,000,000 eggs at one time. After the eggs are laid the adult eels remain in the ocean a few weeks and die. The young eels pass through the larval stage in about three weeks after the eggs start to hatch.

At the beginning of the second spring the young eels start on their trip back to fresh water. Great numbers of them may be seen in the spring at the foot of Niagara Falls where they are blocked by the great cataract. By crawling over stones and along the banks, young eels are able to get above ordinary falls in the streams and rivers.

The eel is a food-fish. The commercial value of the eel is well known to fishermen. They are rich in oil and highly nutritious. Eels vary in weight from three and a half to six and a half pounds and often exceed three feet in length.

117. Importance to Man of the More Common Food-fishes. — The United States, including Alaska, takes from the water about 2,000,000,000 pounds of fish, annually. Alaska produces about one fourth of this total. The hatcheries of the United States have an output of 4,500,000,000 eggs, fry, and small fish.

Some of the fish have been caught in such great numbers that they are growing rather scarce. Some are holding to their normal numbers and a few others are increasing. In the last class belong the carp, kingfish, whiting, Pacific shad, and Pacific herring. Many edible fish are not eaten merely because people do not know about them or perhaps are prejudiced. Examples of such fish are sharks, toadfish, skates, grayfish, burbot, and menhaden.

The Carp. — This is one of our most abundant fishes in the lakes and inland streams. About 43,000,000 are sold

each year in this country. Since this species is hardy, easy to raise, easy to catch, and has high food value it is desirable that more of them be eaten.

The Grayfish. — The grayfish is found along the Atlantic coasts. Although its food value and flavor are equal to that

FIGURE 83. — THE GRAYFISH BELONGS TO THE SHARK FAMILY.
It is very destructive in its food habits, eating the highly prized food-fish. How will the use of this fish for food help the fish industry?

of the tilefish and other food-fishes, it has not been marketable until recently. Unfortunately, when the fish was first named it was called " dogfish " from its biting habits. With that name people would not buy it. Now that it has a better name it is coming into use as a food-fish. Its abundance enables fishermen to offer it for a relatively small price.

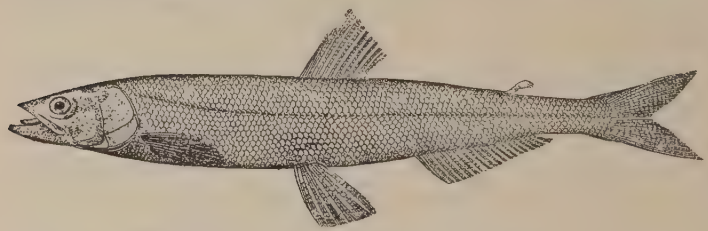

FIGURE 84. — THE WHITING OR EULACHON.
A food-fish recently placed on the market.

The Whiting. — This is another good food-fish that has only recently been in demand as a food. In 1898 less than

50,000 pounds were sold, while in 1908 more than 10,000,000 pounds were marketed. Since that time there has been a constant increase in the consumption of this fish. In England during 1913 about 70,000,000 pounds were sold at a price higher than haddock. The whiting occurs off the coast from New York northward. It can be bought fresh, canned, salted, and smoked.

118. Necessity of Fish Protection. — As the human race increases in number it requires more and more food. Since

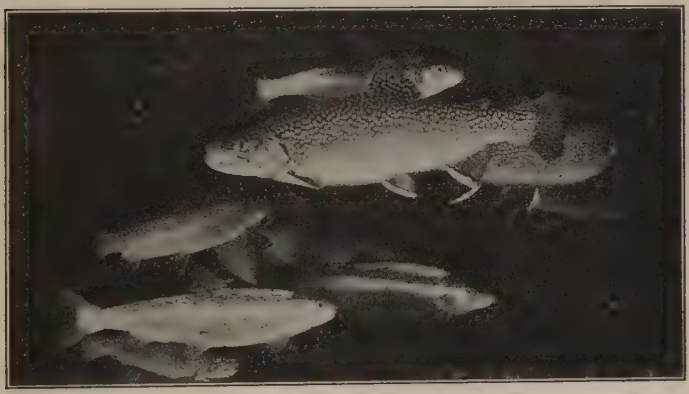

FIGURE 85. — BROOK TROUT.

This is the most highly prized fish among fishermen. It is rapidly becoming extinct except where protected by law.

most people are fond of fish, these animals are caught in ever-increasing numbers by the men who supply the fish markets. These men pay little attention to the necessity of giving the fish an opportunity to lay their eggs undisturbed; so the government has made laws to protect the fish.

During the past twenty-five years in particular the breeding habits of fish have been thoroughly studied, and the breeding period has been the basis for all of the protective laws. This is the reason that the closed season for one kind of fish is different from that for another.

Fish are subject to disease just as men are, and they must be protected from certain disease germs. Also fish which harbor parasites in their flesh are unsuitable for food, and for this reason we should find some way of destroying these parasites. When large numbers of fish are found dead, the state department in charge of fish tries to discover the cause.

The Bureau of Fisheries is one of the subdivisions of the United States Department of Commerce. The original work of this bureau was to inquire into the causes of the decrease of food-fish in order to find means of checking these decreases, and of increasing the supply whenever possible.

During the year 1922 the following studies on fish were carried on: Alaskan and Pacific coast salmon investigation; the fishes of Chesapeake Bay; experimental investigations in fish culture; a study of the diseases and parasites of fish.

119. Fish Hatcheries. — In the natural state, many eggs are laid that never hatch because the sperm cells do not come in contact with them; and of the fishes that are hatched only a small proportion reach maturity. As it is a matter of great economic importance that fishes be saved from extermination and their numbers largely increased, the governments of the world have established hatcheries where fish are raised in great numbers.

In these hatcheries the eggs are taken from the female and placed in a jar, and the mass of minute sperm cells or "milt" is taken from the male and poured over the eggs, so that practically all the latter hatch. Then by giving the developing eggs protection, and the young fish sufficient and proper food, nearly all these eggs develop into active fish and the great loss that comes to the fish developing in their natural environment is prevented. When they are able to take care of themselves, these *fry*, as the young hatchery fish are called, are taken to natural feeding grounds. In New York State and most other states there are state

hatcheries where such fish as shad, pikę, lake trout, salmon, and brook trout, are raised by millions.

The fish that are most useful as food are taken by hooks, nets, and seines, under certain restrictions. Those like brook trout which are caught as much for sport as for food, can be taken only by a hook and line and in certain seasons, the season of the year depending upon the time of spawning. The brook trout spawns in August and September, while the rainbow trout does not spawn until February or March.

120. Humane Methods of Catching Fish. — Every one who has ever been fishing knows that many of the fish caught are too small for use. The protective fish regulations make it illegal to keep them. They should be put back into the water. What is the proper way to remove them from the hook? When taking any undersized fish off the hook, always wet your hand before grasping the fish; otherwise, the dry hand will remove the slime from the back of the fish. This slime is a protection to the fish, for the numerous microscopic plant spores that thrive on fish are unable to gain a foothold except where the slime has been removed. If these spores do get a foothold, they may kill the fish.

The fish that are large enough to keep should be killed as soon as taken from the hook. This can be done by hitting them with a stick on the head, back of the eyes. It will avoid all suffering and make the fish far better for table use.

These two simple things that every one can do are recommended by all of the fish and game commissioners throughout the United States.

OUTLINE

Vertebrates
- Distinguished by
  - Backbone
  - Gill-slits
  - Lungs
  - Nervous system

Fishes
- Body
  - Head
  - Trunk
  - Tail and Fins
  - Scales

- Life Processes
  - Locomotion
  - Food-taking
  - Respiration
  - Circulation
  - Excretion
  - Nervous system
    - Special senses
  - Reproduction
    - Spawning
    - Care of young
- Kinds of fishes
  - Eel
    - Life history
  - Carp
  - Grayfish
  - Whiting
- Fish protection
  - Hatcheries
  - Humane methods of catching fish

SUMMARY

Vertebrates are distinguished from invertebrates by having backbone, gill-slits or lungs, and a well-developed nervous system. Fishes are a good illustration. They have head, trunk, tail, fins, scales, and have all the life processes of the other animals which we have studied. There are many kinds of fishes, most of which are or may be, used as food. Their economic importance is enormous. Because of this there are laws for fish protection and the various governmental bodies have established fish hatcheries, where the young may be brought to maturity under protection from their natural enemies.

QUESTIONS

What are the chief differences between vertebrates and invertebrates? What do land vertebrates have to correspond to the gill-slits of a fish? Of what three parts does the body of a fish consist? What are the fins? the scales? Describe the life processes of the fish. Have they any special senses? What is "spawning"? How do fishes care for their young? How many kinds of fishes do you know? Are they all good to eat? How important is the fish industry to man? What methods of fish protection are practiced and by whom?

REFERENCES

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Jordan and Evermann, American Food and Game Fishes.

CHAPTER XI

FROGS AND THEIR WAYS OF LIVING

When by night the frogs are croaking, kindle but the torch's fire;
Ha! how soon they all are silent!

— LONGFELLOW

121. Amphibians. — Frogs and toads are the best known animals of this group; but here belong also the *Salamanders* (săl′ȧ-măn-dērs), frequently miscalled *lizards* (see page 164). The *amphibians* (ăm-fĭb′ĭ-ans: Greek, *amphi*, both; *bios*,

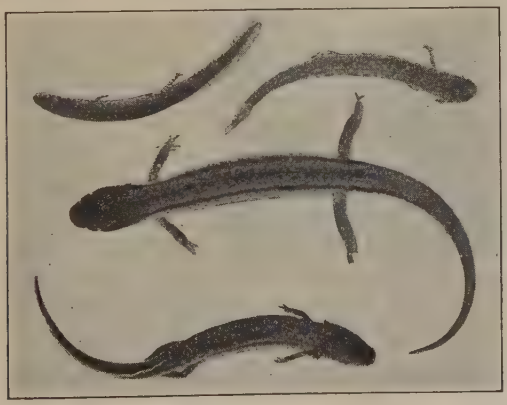


FIGURE 86. — SOME COMMON SALAMANDERS FOUND ON LAND.

life) are all small, the largest one found in America being a salamander (*Cryptobranchus*), which is rarely more than two feet long. This term amphibian is used to explain the habit which frogs, toads, and certain salamanders have of

spending their larval (tadpole stage) life in the water and their adult life on land, or partly on land and partly in the water.

LABORATORY STUDY

Place one or two frogs or toads in a small jar or box and observe the points mentioned in the report below.

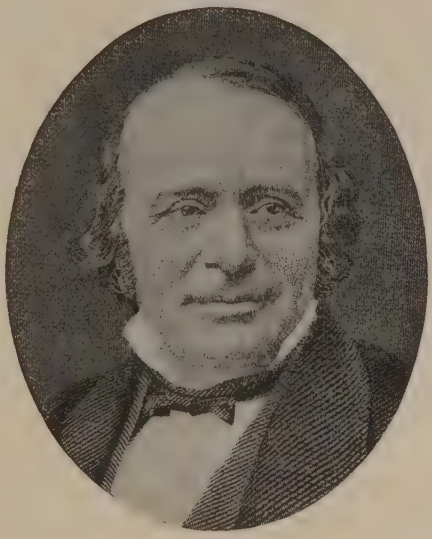
Do They Wink?	Can They Protect Their Eyes?	How Do They Get Air?	Can They Walk? Hop?	How Do They Swim?	How Do They Catch a Fly?

122. Frogs. — The general form of the body, the shape of the head, the long hind legs adapted for jumping, and the webbed toes for swimming are much the same in all frogs. There are several kinds, one of which, the leopard frog, is found generally distributed throughout the United States. It can be recognized by the presence, on the back, of many brownish or greenish spots, edged with white, which help the frog to escape the notice of his enemies as he squats among the water weeds. These colors form rather definite bands on the hind legs, though there is much variation.

FIGURE 87. — LEOPARD FROG.

LABORATORY STUDY

Compare the general shape of fish and frog. How do the colors differ? Show how the legs and feet are adapted to the way the frog



Jean Louis Rudolphe Agassiz was born in Switzerland, in 1807, and died at Cambridge, Massachusetts, in 1873. Agassiz introduced the laboratory method in zoölogy to students of America and trained many who have become prominent in biology. His motto, "Study nature, not books," has been taken as a motto by thousands of students all over the world. He was the founder of the summer laboratory method of study now so common, the first such laboratory having been held at Penikese Island off the coast of Massachusetts. He was Professor of Zoölogy and Geology at Harvard and curator of the museum that now bears his name. His scientific contributions covered a wide range of subjects in zoölogy and geology.

lives. Is the frog sensitive to touch in various parts of the body? Examine the eyes. Open the mouth and see that the frog can draw in its eyes. The ear membrane is on the side of the head back of the eyes. Pass a probe through the ear membrane of a dead frog and see where it comes out in the mouth. This is the opening of the Eustachian tube. How far can the living frog see? Notice the method of breathing. See the throat move up and down. Hold the frog under the water and gently rub its sides. It will usually croak. Thus we can prove that the frog is able to make the air travel from his lungs to his mouth and back again while under water.

123. Food-taking. — Frogs are greedy creatures. They will eat almost any animal small enough to be swallowed, such as insects, worms, snails, tadpoles, and small frogs. These are caught alive and when in motion. The frog has a sticky tongue with a forked end for catching small insects.

124. Respiration. — The lungs are hollow sacs that lie back of the stomach, one on each side. In the freshly killed animal, these can be filled with air by inserting a blow-pipe into the windpipe and blowing air into them. The empty lungs are about as large as the blunt end of a lead pencil.

The oxygen of the air passes through both the skin and the lungs into the blood of the frog, and the carbon dioxide of the blood is thrown off through these same two organs. The frog has large blood vessels close to the skin, especially along the back. These send many fine branches into the skin. This explains why the frog can " breathe " through its skin. When the frog remains under the water for a long time, as during the winter, all the oxygen used enters the blood through the skin. When the air is taken into the mouth, it is forced into the lungs by the muscles on the floor of the mouth. In a way, the air is swallowed into the lungs rather than breathed in as in the case of mammals. Experiments have been made which show that the frog can get oxygen in sufficient quantities to maintain life, even if it has not the use of its lungs. The frog thus possesses two organs of respiration, the skin and lungs.

125. Digestion. — The mouth is large. Short lips cover the short teeth in the edge of the upper jaw. The tongue, which has two fleshy horns at the back end, is attached by the front end to the floor of the mouth. The frog can

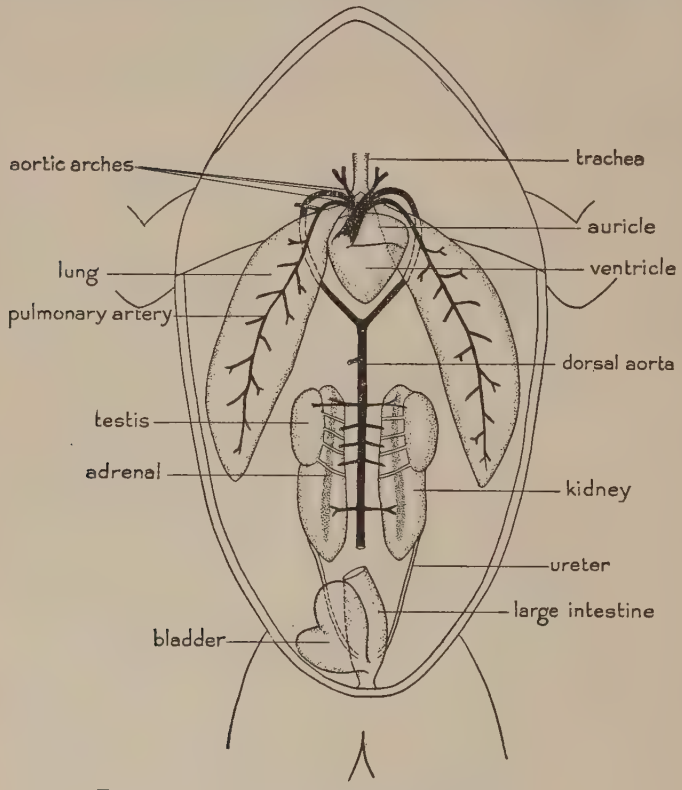


FIGURE 88. — DIAGRAM SHOWING ORGANS OF FROG.

throw its sticky tongue over the tip of the lower jaw and use the forked end to catch insects which are then carried into the back of the mouth. Two groups of little curved teeth in the roof of the mouth aid in preventing the escape of the prey. The food is swallowed whole. The esophagus

(the tube connecting the mouth cavity and stomach) of the frog can be stretched so that a comparatively large animal can be swallowed. There is no sharp limit between the esophagus and the stomach, which is a long, spindle-shaped sac (Figure 89), larger than the rest of the digestive tube.

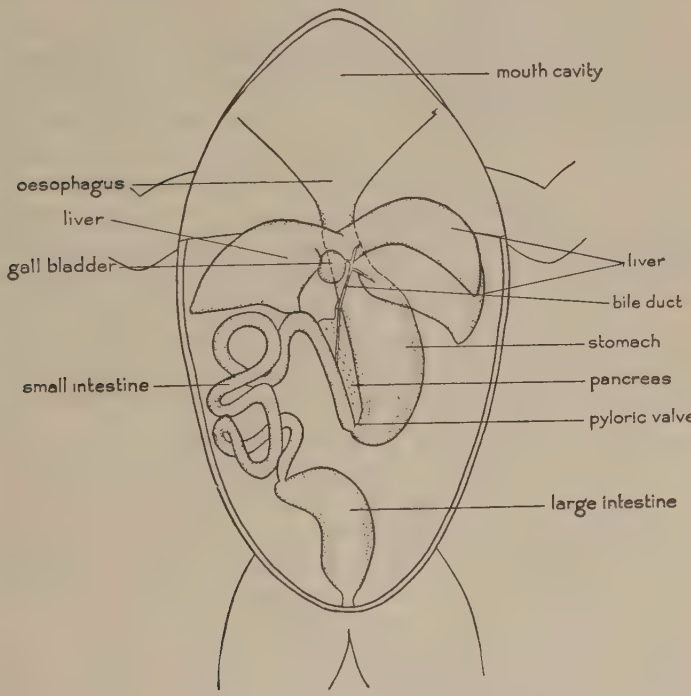


FIGURE 89. — DIGESTIVE TRACT OF FROG.

The small intestine begins at the back end of the stomach as a small tube which makes several turns, and finally enlarges into a region called the large intestine, the last part of which is termed the *cloaca* (clō-ā′cà) or common sewer.

Two glands of importance belong to the digestive organs — the liver and the pancreas. The liver is a large, dark red,

three-lobed organ that covers the ventral (lower) surface of the stomach. The pancreas is a whitish, small, irregularly shaped body attached between the stomach and the intestine. Both these glands drain into the intestine just beyond the stomach. The bile secreted by the liver is at first collected in a sac called the gall bladder.

All these parts of the alimentary canal are held in place by a thin membrane, the *mesentery* (mĕs'ĕn-tĕr-y), one edge of which is attached to the dorsal wall along the line of the backbone and the other to the stomach and intestine. A small gland (the *spleen*) is found in this mesentery. The spleen has no duct connecting it with any other organ in the frog. Blood vessels run through the spleen, a fact which scientists believe is important in making new blood corpuscles.

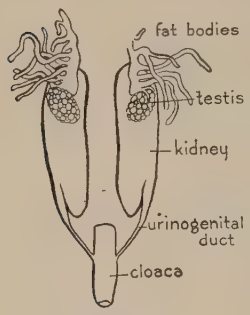


FIGURE 90.

Diagram to show the relations of the testes to the kidneys and the relation of the kidneys to the intestine(cloaca).

126. Excretion. — This fundamental life process is performed in the frog as in all other vertebrates. Like the fish, it has a pair of kidneys that remove the wastes from the blood in the form of liquids; while the skin and lungs allow such wastes as the gas, carbon dioxide, to be discharged from the blood.

The kidneys are small red bodies lying close to the back. Each one is connected with the cloaca by a minute duct (ureter or urinogenital duct). The urinary bladder is attached to the cloaca (Figure 90).

127. Reproduction. — The fundamental process of reproduction in the frog family is the same as in all other animals, but there is introduced the tadpole stage which makes the reproduction of the amphibians different from that of any other vertebrate.

The male frog has a pair of spermaries (spĕr′mȧ-rĭz), one attached to the front (anterior) end of each kidney (Figure 90). Each spermary (testis) is yellow in color. The sperms escape through the kidney. In the female frog, ovaries, sometimes filled with eggs, are easily seen. A long, closely coiled pair of oviducts (ō′vĭ′dŭkts) opens in front near the forward end of the stomach and in the back into the cloaca. The eggs break through the wall of the ovary and enter the oviducts. As the eggs pass down through the oviducts, they are coated with a jelly-like covering that swells in the water. This jelly covering protects the eggs.

At the anterior end of each kidney in both the male and female frog is to be seen an irregular mass, the fat body, which contains stored energy that the frog uses as it begins to grow eggs or sperms in the early spring before there is plenty of food.

128. Irritability. — In all vertebrates this life process is limited to the nervous system, which includes brain, spinal cord, nerves, and sense organs described below. Animals with definitely developed nervous organs and a specialized brain as in vertebrates are able to do more things than a worm, for example. The brain of a frog is really a very simple organ when compared with the brain of a dog. This is the main reason why a dog can be taught to do so many more things than a frog.

129. Nervous System. — The nervous system of the frog is more highly developed than that of the crayfish. It consists of a central part inclosed in the backbone and cranium (braincase). This central nervous system in all vertebrates is always found above the digestive tube, and is divided into the brain and the spinal cord, from which numerous nerves arise and extend to all parts of the body.

The parts of the brain are the same as in man and much easier to study. Beginning at the front (anterior) end of the brain the parts are as follows: (1) small *olfactory* (ŏl-făc′-

tō-rў) lobes, which are not sharply marked off from the rest of the brain, and, as shown in Figure 91, connect with (2) the *cerebral* (sĕr′ē-bral) hemispheres, which are oval in outline. (3) A short mid-brain region, partly covered by the back part of the cerebral hemispheres, connects the front and back part of the brain. (4) Two large *optic* lobes, the widest part of the brain, are just back of the mid-brain. (5) The *cerebellum* (sĕr-ē-bĕl′lŭm) of the amphibians is small and easily overlooked (Figure 91). The last region of the brain is the (6) *medulla* (mē-dŭl′là), which is occupied by a large triangular cavity called the fourth ventricle.

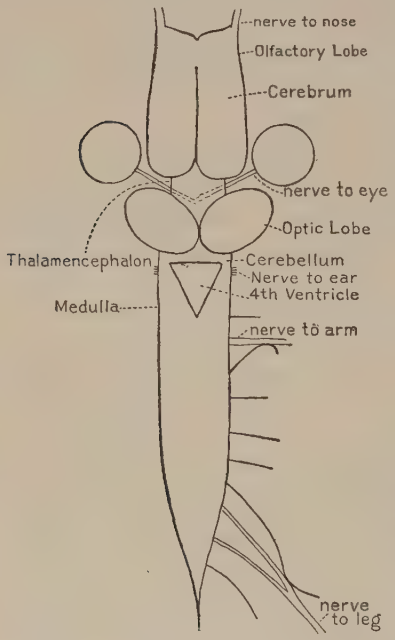


FIGURE 91.—CENTRAL NERVOUS SYSTEM OF FROG.

The work which each of these regions of the brain does is not sharply defined. The olfactory lobes receive the smell stimuli. The cerebral hemispheres control muscular action. When the latter are removed, the frog loses all power to initiate any movement and will sit still in a dry, warm room for hours unless disturbed. This he never does when the cerebral region of the brain is uninjured. The mid-brain region is the passageway for all nerve-pathways that travel to and from the brain. The mid-brain and optic lobes explain to the frog the sight stimuli. In the frog, the cerebellum, which is poorly developed, is less im-

portant than in man. The medulla gives off more nerves than any other region of the brain. Here are found the nerves leading to the face, tongue, ear, heart, and lungs. While there is a great difference between the shape of the parts of the frog's brain and those of man, yet the work done by each region is of the same kind.

The brain joins the spinal cord, without any external sign to indicate where one begins and the other leaves off. A definite number (ten pairs) of nerves leaves the brain proper. These are devoted to the special senses of the head and to moving the muscles of the throat and head. The frog has ten other pairs of nerves joined to the spinal cord (Figure 91). In a long salamander there are twenty or thirty pairs of nerves on the spinal cord.

LABORATORY STUDY

In connection with the study of the frog, the following additional laboratory work should be done in order that the several organs of man which are discussed in Part III may be better understood. Frogs that have been preserved in formalin can be easily dissected. Wash them well in water to which ammonia has been added. Examine the digestive organs: first the mouth, then the esophagus, stomach, small and large intestine, and cloaca. For convenience, the liver will have to be removed. The pancreas can be seen as a small whitish structure in the loop between the stomach and the intestine. The spleen is a round red organ usually found near the large intestine.

A pair of narrow kidneys lies close to the back and is connected by ducts with the cloaca. The spermaries are found attached to each kidney near the front end and the sperm cells escape to the exterior by the kidney ducts. In the female frog the large ovaries occupy most of the space of the body cavity. A pair of oviducts opens into the body cavity just back of the stomach. The eggs escape from the ovary into the body cavity.

The nervous system is inclosed in bone that is easily removed from the dorsal surface. The brain should be studied and the following divisions recognized: cerebral hemispheres ending in front in the olfactory lobes, which are not clearly marked. Just back of these are the two large roundish optic lobes which are attached to the mid-brain

thalamencephalon (thăl-a-mĕn-cĕph'â-lŏn). The cerebellum is small and the medulla passes into the spinal cord without any sharp dividing line.

130. Life History of the Frog. — Late in March and early in April the frogs gather in ponds to lay their eggs. The eggs are surrounded by a jelly-like substance which holds them together. As the eggs are being laid by the female frog, the male frog spreads a large number of sperm cells over the whole mass. These sperm cells make their way

FIGURE 92. — FROG EGGS.

through the soft jelly and one of them must enter each egg or it cannot grow into a tadpole.

Fertilization of the Egg. — As soon as the sperm cell enters the egg (Figure 93), it begins to change from a solid, pointed body into a round nucleus which is so much like the nucleus already in the egg cell that none but experts in this study can tell which came from the sperm cell and which from the egg cell. These two nuclei come in contact and unite, leaving but one nucleus in the egg (Figure 93). This last change is fertilization, which is defined as the union of the contents

of the egg and the sperm nucleus. After this union is completed the egg begins to divide into cells, as shown in Figure 94, and finally a tadpole is grown.

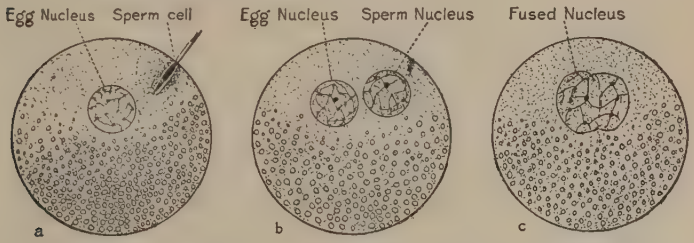


FIGURE 93. — DIAGRAM ILLUSTRATING FERTILIZATION IN FROG EGG.

a. The sperm cell is penetrating the cytoplasm of the egg; *b*, the head of the sperm cell has become transformed into a nucleus; *c*, the egg-nucleus and the nucleus derived from the sperm head fusing. This fusing is fertilization.

Growth of the Tadpole. — As soon as the young tadpole hatches, it attaches itself to plants and lives for the first few days upon the food-yolk within its own body; the mouth forms, and horny jaws develop. Then the tadpole begins to feed upon minute plants and becomes dependent upon its own skill to get food and escape its enemies.

For a time the tadpole breathes through gills. Two sets are used. The first ones are on the outside of the body and last for only two or three days, when internal gills form in the throat and the tadpole breathes much like a fish.

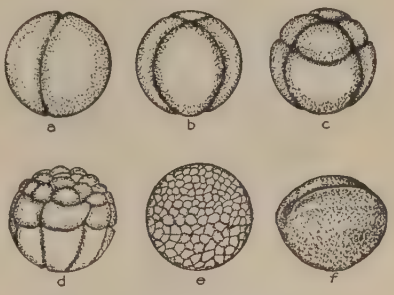


FIGURE 94. — DIVIDING EGG OF FROG.

After the egg has been fertilized as shown in Figure 93, the embryo begins to divide in a regular manner. *a*, Two-celled embryo; *b*, four-celled embryo; *c*, eight-celled embryo; *d*, thirty-two to forty-eight-celled embryo; *e*, many celled stage; *f*, embryo beginning to form central nervous system.

The Tadpole Becomes a Frog. — In the growth of the tadpole into a frog the hind legs appear first. Later the front ones begin to show and as they develop the tail is gradually absorbed. While these external changes are going on, there are many complicated internal changes taking place; internal gills are disappearing and lungs, nerves, blood vessels, and muscles are being formed to give the new legs life and action. The internal lungs take the place of the gills in the throat before the legs are fully grown, and such tadpoles must rise to the surface to breathe air. Explain in Figure 96 which tadpoles breathe by lungs, and which by gills. This complicated way of growing into a frog is called *metamorphosis* and this term has the same general meaning as when used to describe the growth of insects (page 58).

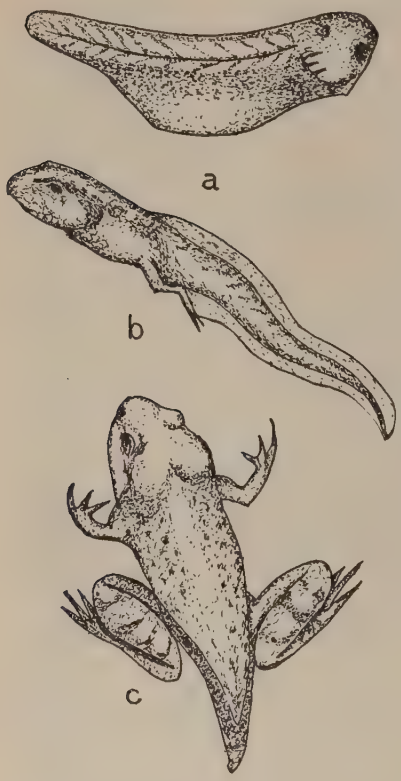


FIGURE 95. — THE EMBRYO BECOMING A TADPOLE.

a, first stage; *b*, second stage; *c*, third stage.

The tadpoles of leopard frogs become small frogs in a single summer, but the tadpoles of bullfrogs and green frogs require two seasons to complete their development. These latter tadpoles hibernate in the mud with adult frogs and toads.

131. The Frog's Habits and Means of Protection. — Frogs are seldom found far from some pond or stream on the bank of which they are usually seen. When disturbed, they jump into the water, swim to the bottom, stir up the mud, and quietly come to rest a short distance from the place where they entered. They are protected also by their color, which usually resembles the grass and rocks among

FIGURE 96. — TADPOLES.

The smallest tadpole, black, on the bottom of the aquarium jar is a toad tadpole about three months old. The other two tadpoles on the bottom are frog tadpoles about three months old; while the two tadpoles with legs are frogs. The larger is about one year old and the smaller three months old. This marked difference in size and growth is natural, as each kind takes a different length of time to go through metamorphosis.

which they live. When away from water frogs often escape their enemies by their remarkable leaping ability. As the frog's hind legs are considered a delicacy, man is the worst enemy of the frog. Next come the snakes, birds, and fish. The leech kills frogs by sucking their blood. Fish eat many of the tadpoles, and, strange to say, some water beetles eat tadpoles also.

As the nights in the fall grow cool, frogs make ready to spend the winter in a state of inactivity. During the warmer part of the day they may be seen sunning themselves on a bank, but as soon as ice forms on the water they remain on the bottom or buried in the mud. The lungs are emptied of air, the heartbeats decrease, and all the usual life processes take place more slowly. This habit of passing the winter in a state of inactivity is known as *hibernation* (hī-bĕr-nā′shŭn). All the Amphibia, reptiles, and several of the mammals hibernate during the winter.

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FIGURE 97. — TOAD.

132. The Toad. — While there are several different kinds of frogs in the United States, except in the southwest, there is but one kind of toad that is at all common. This homely animal is one of our best friends, for he lives on insects and slugs that destroy the plants in our gardens. He captures his food by throwing out a sticky tongue just as the frog does.

One often hears the expression, "Don't touch a toad, you will have warts." Of course this is not true, nor is it true that they are found alive in solid rocks. Sometimes they fall into crevices and are released when the rock is blasted away. If they have been in this crevice-prison only a short time, they are often alive, but we must remember that they require food like all other animals and soon starve unless they can secure it.

133. Life History of the Toad. — In many respects the toad's life history is similar to that of the frog. The eggs

of the toad are laid in stagnant water in strings of a jelly-like substance. (Figure 98.) The eggs hatch in from five to ten days into wriggling tadpoles, which feed on the microscopic plants that are found in water. They swim by means of their tails. Respiration is accomplished by means of the outside gills, which allow the oxygen from the water to reach the blood and the carbon dioxide to enter the water. Later the inside gills take over the work of the outside gills and the outside gills disappear. Still later, as lungs begin to develop, the tadpoles come to the surface for air, so that for a time they

FIGURE 98. — DIFFERENT STAGES IN THE LIFE HISTORY OF THE TOAD.

are getting the oxygen both from the air and the water. (See Figure 96.)

About this time the hind legs begin to appear, the tail shortens and, soon after, the front feet may be seen. By the first of July the tail has entirely disappeared and the small toad begins to hop around on the bank, having the form, attitude, and habits of the toad as we see him in the garden. From the bank they begin to travel away from the water and scatter over the country in all directions. After a rain or during a shower, thousands of them are sometimes found hopping along a ravine or highway. Here they are run over by man and beast and fed upon by crows and other enemies. Of the hundreds that leave the pond but very few ever live to be a year old. Since toads feed on a great variety of harmful insects they are recognized as beneficial

animals. Although slow-moving, the toad is able to feed upon many flying insects, which he strikes with his quick-moving tongue as they rest on plants or crawl over the ground.

134. Evolution. — The study of the changes through which the egg of the frog grows into a tadpole and then into

FIGURE 99. — A GROUP OF FOSSIL ANIMALS.
These were once abundant, but they are now extinct.

a frog tells us much about the way frogs may have developed or evolved from fishes. The tadpole breathes and eats like a fish; but as soon as lungs and legs are formed, it breathes and eats like a frog. This same study of the tadpole also illustrates how animals may gradually have come to live on land, and suggests a natural explanation for the origin of land vertebrates. In the early history of the earth there were hundreds of animals and plants which are no

longer known to science. The skeletons, footprints, and whole bodies of many of these are preserved in the rocks. Such remains are called *fossils*.

If all the animals, or one of each kind, had been preserved in the rocks, it would be easy to investigate these earlier animals and their relation to the living animals of the present. But in our information there are great gaps, which we are, however, gradually bridging. Apparently unrelated animals have resemblances, so that in time we may come to see that all animals are really related forms, varying only in complexity of structure. One thing that we must always keep in mind is that the plants and animals which live now are but a small fraction of those which have lived. The rocks have preserved the remains of only a small part of the forms of the past. Many of the records of extinct animals and plants have been destroyed by decay and heat so that much that would be valuable in solving the question can never be found. Evolution thus means that all of fossil and modern animals and plants have had a continuous history.

FIGURE 100. — A FOSSIL LEAF.

The study of the development of the frog also illustrates two other general subjects, *heredity* (hē-rĕd′ĭ-tў) and the influence of *environment* (ĕn-vī′rŭn-ment) if reproduction is to be successful.

135. Heredity. — The tendency of all young animals to grow and live like their parents is called *heredity* and may

be defined as the transmission of physical and mental traits from parent to offspring. There is no difficulty in recognizing the young frog as a certain kind of frog. The color markings on the skin are like those of the parents; it grows to about the same size; it eats the same kind of food, and lives in the same region.

FIGURE 101. — TREE FROG.

Note the discs at end of toes. Compare the environment of leopard frog and tree frog.

Every species of living thing is able to produce new forms like itself, and heredity is always at work when new plants and animals are being produced. Thus heredity determines that leaves of the right shape and size occur in the proper place or that fins in the fish or legs in the frog shall form in their normal position.

A detailed statement of the laws of heredity is beyond the province of an elementary book, but it is now well established that certain traits of parent plants and animals are reproduced in their offspring in regular and definite amounts and proportions. This is more fully discussed in Part V.

136. Environment. — This word is used in two ways. First, it refers to general surroundings such as temperature, moisture, and seasons, as they vary from year to year; and secondly, to immediate surroundings. The frog responds to the first by hibernating in the winter; while the second phase of environment may be illustrated as follows: the

tadpole can live only in water, and if the pond dries up before the frog stage is reached, the environment has become unsuited to the tadpole. This often happens when the eggs are laid in a temporary roadside pond which evaporates long before the tadpole becomes a frog. All such tadpoles die unless they are able to swim to some other body of water.

The birds that are able to fly avoid hibernating in the winter. They are able to adapt themselves to the change in the seasons without burying themselves in the mud as the frogs do.

Some of the birds do not migrate, but remain all winter in the north. They have become so well adapted to conditions that they are able to get their food where birds that migrate would starve.

Man is the only animal that is able to live anywhere on the face of the earth under the most varied conditions. To realize this fully we have but to think of the different surroundings of the Eskimo, Indian, Bushman, and of ourselves.

Each animal and plant is directly dependent upon its environment for food and a home.

137. Economic Value of Amphibians. — The toad is the only member of the amphibian group that is of any great value to man. It destroys many insects. Frogs eat a few, but hardly enough to entitle them to high rank as beneficial animals. Their chief value is as food and as convenient forms for dissection in biology courses.

OUTLINE

- Amphibians
  - Defined
  - Salamanders
  - Frogs
    - Life processes
      - Food-taking
      - Respiration
      - Digestion
      - Excretion
      - Reproduction
      - Irritability
    - Nervous system
      - Spinal cord
      - Brain
        - Olfactory lobes
        - Cerebral hemispheres

- Mid-brain
- Optic lobes
- Cerebellum
- Medulla

Life history
- Fertilization of egg
- Growth of tadpole
- Tadpole becomes frog
- Metamorphosis

Habits
- Jumping
- Protection
- Swimming
- Hibernation

Toads
- Life history
- Similar to frog

Evolution
- Heredity
- Environment

Economic value of amphibians

SUMMARY

The amphibians live both on land and in the water. The best known are frogs, toads, and salamanders, commonly called lizards. The frog is so well known that it is here taken as a type to study. It has all the life processes of the other animals we have studied, though of course these vary in the way each is carried out. The brain and nervous system of the frog are much more highly developed than those of the crayfish. The parts of the brain are the same as in man.

The life history of a frog begins with the eggs, which are laid in ponds early in the spring. After fertilization the egg develops into a tadpole, which gradually grows legs and loses its tail. Meanwhile complicated changes take place inside. Frogs have protective coloration, and in winter they hibernate.

The toad has practically the same life processes and life history as the frog. It is of greater economic importance to man because of the large number of insects it eats.

Our study of the life and development of the frog helps us to understand what the scientists call evolution. It also illustrates heredity and adaptability to environment. Heredity is the tendency of the young to be like the parents. Environment refers to the surroundings of life and the conditions under which animals live.

QUESTIONS

What are amphibians? Why are they so called? Name three classes. Which is the most suitable for detailed study? Which is of the most importance to man? How does the development of the brain of a frog compare with that of a crayfish? How about the nervous system? Describe each of the life processes of the frog. Has the

brain of a frog the same parts as that of a man? Name these parts. How do frogs reproduce? What does the egg become? What is the next stage in the frog's life history?

Does the toad have the same life processes as the frog? The same life history? Why are toads economically important to man? In what way does our study of the frog illustrate evolution? What is meant by heredity? By environment?

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CHAPTER XII[1]

But the trail of the serpent is over them all.
— MOORE

A GROUP OF VERTEBRATES THAT HAVE BECOME NEARLY EXTINCT

138. Reptiles. — When one examines the fossils of the ancient group of reptiles in any of the great museums one is impressed by their huge size and strength. This enabled them to kill in combat all other kinds of animals of that

FIGURE 102. — DINOSAUR.

This animal is known only through its fossil remains. Modelled from a restoration by C. W. Gilmore. This extinct reptile was probably 87 feet long and 15 to 16 feet high at the hips. One of the largest animals known to science. Photograph furnished by the United States National Museum and published with their permission.

period and is the reason why we call the time when these large animals were living the "Age of Reptiles." There was a time when reptiles were not only much larger than they are to-day but more numerous. For some reason that we have not been able to discover, the reptiles of this ancient

[1] If desired, this chapter may be omitted without affecting the sequence in the book.

period became largely extinct. A few, however, were able to adapt themselves to changing conditions and their descendants are the lizards, snakes, alligators, turtles, and crocodiles of the present. The *Reptilia* (Latin, *repere*, to crawl) are characterized by a covering of bony plates, or scales, in the skin,

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FIGURE 103. — THE OLDEST LIVING ANIMAL.
Said to be 150 years old.

by the absence of gills in the adult stages, and by the presence of lungs.

139. Life History. — Unlike the amphibians, the reptiles hatch directly into their adult form, only much smaller. The young snake just out of the egg or the young alligator just hatched is recognized by its resemblance to its parents.

There is no metamorphosis, as in the frog. The reptiles

lay their eggs in protected places and exhibit no parental care for the eggs or for the young. Some snakes hatch their young in the body of the parent and the offspring are born alive.

140. Turtles. — Turtles are easily recognized by their outer skeleton. This skeleton is unlike the skeleton of the starfish or crab, or of any other group of animals. The skeleton of the turtle, composed mostly of skin plates, is something like a box with a cover, the upper portion corresponding to the box itself, and the lower portion to the cover. The box

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FIGURE 104. — LIZARD.

does not fit closely all the way around, for there are places where the head, the tail, and the four legs stick out. When the turtle is disturbed, the legs, the head, and the tail are drawn inside, and the box is pulled down tightly by muscles to meet the cover.

The term turtle is often applied to aquatic forms, and the term tortoise to those living on land. Sea turtles attain a length of six or eight feet and weigh sometimes as much as a thousand pounds. The flesh of the green turtle and of the *terrapin* (tĕr′rȧ-pĭn) is used for food.

141. Lizards. — There is a great variety of lizards. A common lizard is the *chameleon* (kȧ-mē′lē-ŭn), which has the

power of changing the intensity of the color in the skin by moving the color material nearer the outer surface or drawing it away. The horned toad of the Western United States is a lizard with scales of varying length which give it a horny appearance. Horned toads, instead of laying eggs, have the eggs hatched while yet in the oviducts and the young horned toads are born alive. A poisonous lizard is the *Gila* (hē′lȧ) monster that occurs in New Mexico and Arizona. It has the poison glands in its lower jaw.

142. Snakes. — Snakes are legless vertebrates with long, cylindrical bodies covered with scales. They move by means of the scales (*scutes*) on the under side of the body. Since snakes eat insects, frogs, mice, rats, and rabbits, they should be considered beneficial.

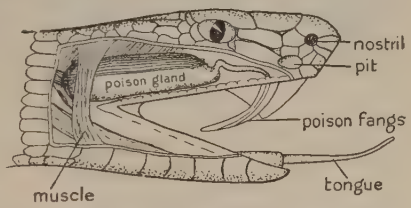

FIGURE 105. — HEAD OF RATTLESNAKE.
This shows the poison gland and its connection with the fangs which are specialized teeth.

Rattlesnakes[1] and copperheads are the most common poisonous snakes of our country. Their jaws are provided with fangs (Figure 105), by means of which a poison is injected into their prey. Large snakes like the *boa constrictor* of South America, and the *python* (pī′thŏn) of Asia are constrictors. They are able to wind their bodies around their prey and to crush it to death. The most deadly snake in the world is the *cobra* (kō′brȧ) of India, where thousands of the natives die annually from its bite.

Snakes swallow their food whole, and as the teeth are used merely for holding their prey, they point backwards.

Fear of Snakes. — In the case of many grown-up people there is a senseless fear of even the smallest snake. Small

[1] The two most common rattlesnakes are the mountain rattler and the *massasauge* (măs-sa-sä′ge).

FIGURE 106. — RATTLESNAKE — POISONOUS.
Notice the triangular shape of the head and the small pit on each side of the nose. Compare with Figure 110.

children are seldom afraid of snakes until some older person tells them that snakes are poisonous or that they will be bitten if they handle them. As a matter of fact the common snakes of the garden will not bite when carefully handled but rather seem to like to be handled. When one stops to think that snakes are cold-blooded while the hands are warm it is not strange that they might come to enjoy the human hand. Some people are so frightened when they see a snake that a whole day of pleasure may be spoiled on this account. It is unwise to put fear where there should be none and it is unwise to imagine that a harmless snake will bite. Fear takes a toll of our nervous energy and if we can learn to banish senseless fear

FIGURE 107. — RATTLES OF RATTLESNAKE.

we have done something towards prolonging life and making our lives more efficient.

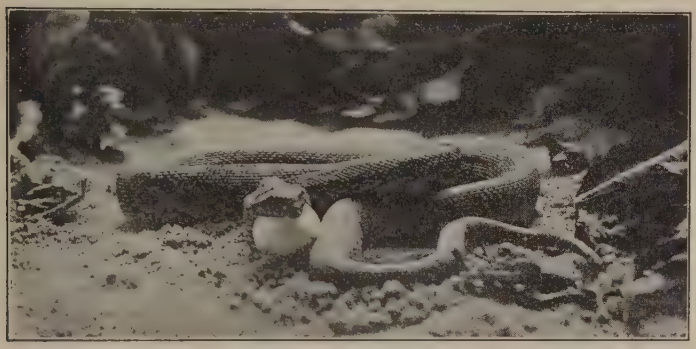

FIGURE 108. — BULL SNAKE WITH HEN'S EGG IN MOUTH.

We need to learn about snakes enough to tell the harmless ones from the poisonous ones and also enough to overcome our fear of the little snakes. If one does not fear

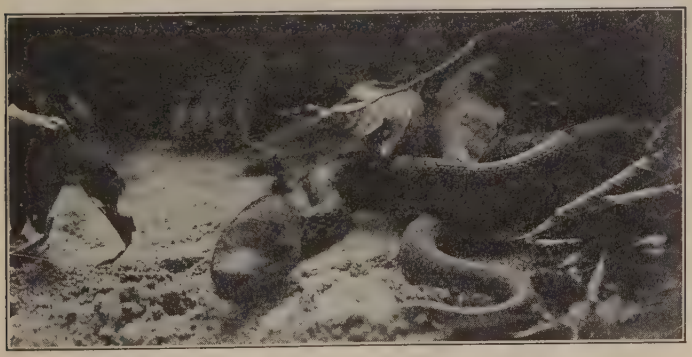

FIGURE 109. — BULL SNAKE AFTER SWALLOWING EGG.

snakes and can handle them without minding, it is not wise to run after others with a snake in hand. People cannot be frightened out of their fears. A better way is to show

them by handling a snake gently that it will not bite and that it enjoys being handled.

143. Alligators and Crocodiles. — Crocodiles are found in the Southern United States, South America, Africa, and India. Alligators are found in stagnant pools in the Southern

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FIGURE 110. — GARTER SNAKE AND SEVENTEEN YOUNG.
This snake is harmless.

United States. Crocodiles resemble alligators but have narrower mouths.

144. Adaptations. — Reptiles are peculiarly adapted to their environment. Snakes that live in trees are sometimes the color of leaves or bark. Some that are harmless are colored much like poisonous snakes. An adaptive feature of the crocodile is a fold of skin which shuts off the mouth from the throat and prevents water from entering the throat while the crocodile is drowning its prey. The old world chameleons have their feet modified for clasping branches. In

the case of the turtles, those that live in the sea have paddle-like feet for swimming, while those that live partly on land and partly in the water have toes with webs. Lizards are almost always of about the same color as their surroundings.

With permission of New York Zoölogical Society.

FIGURE 111. — ALLIGATORS.

SUMMARY

The reptiles always use lungs for breathing. They usually have scales or bony plates in the skin and have either two pairs of appendages (turtles, lizards, alligators, crocodiles) or none (snakes). It is important to learn to recognize poisonous reptiles, as their bite is dangerous.

LABORATORY DIRECTIONS

From models or preserved specimens the difference between the harmful and harmless reptiles should be worked out. The living turtle can be studied easily. Its special skeleton is an illustration of protective adaptation. Notice how the nostrils of the aquatic turtle can be closed. How does this help the turtle?

QUESTIONS

What are the most common snakes in your vicinity? Are they poisonous? How can you tell? Where do they live? What do they eat? How many kinds of turtles do you know? Where do they live?

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CHAPTER XIII

BIRDS

Ye call them thieves and pillagers; but know
They are the winged wardens of your farms,
Who from the cornfields drive the insidious foe,
And from your harvests keep a hundred harms;
Even the blackest of them all, the crow,
Renders good service as your man-at-arms,
Crushing the beetle in his coat of mail,
And crying havoc on the slug and snail.

— LONGFELLOW

145. Classification of Birds. — Birds are usually divided into groups according to their structure. The shape and size of the beak and of the feet and wings are the characteristics most used in the general classification. This is illustrated by a single group of birds, the hawks, owls, and vultures, which are given the technical name of *Raptores* (răp-tō′rēz : Latin, *rapere*, to seize), birds of prey. The bird books describe the Raptores as follows : toes four, three in front and one behind, except in the vultures; all toes armed with strong, sharp, curved *talons* (tăl′ŭnz); bill with a *cere* (sēr : Latin, *sera*, wax) or covering of skin at its base through which the nostrils open, very stout and strong, the upper mandible tipped with a sharp-pointed hook.

In addition to this classification by structure, which is essential for a careful study of birds, they are also classified by their habits. For example, birds are divided into four classes based on their migratory habits. Birds like the downy woodpecker and English sparrow are permanent residents throughout their range, that is, they can be found

within given limits at any time of year, while bobolinks and humming birds are summer residents, migrating southward at the end of the season. Birds like wild geese, fox sparrows, and the like, are transients, stopping along their migratory route for rest or food or to escape unfavorable weather; while such birds as the snowy owl, northern shrike, and evening grosbeak are winter visitants which migrate to us from the North when the cold becomes excessive and the food supply is diminished.

FIGURE 112. — SHRIKE.
A small bird of prey.

Birds are classified also by their nesting habits. Some birds, like the meadow lark and bobolink, nest in the open field, and their nests are made inconspicuous rather than inaccessible; other birds, like certain hawks and eagles, build their nests in tall trees, making them conspicuous, but inaccessible. Still others build like the oriole at the end of slender branches where they are out of reach of animals. Birds like the kingfisher, sand swallow, and puffins build their nests at the bottom of a burrow in the ground.

146. Nest-building. — Birds show great variation in nest building. Some build a large nest with materials loosely

put together; others build small nests of neatly woven material, and some birds, like cowbirds, build no nest at all, but lay their eggs in the nests of other birds and leave the work of caring for their young to the foster parents.

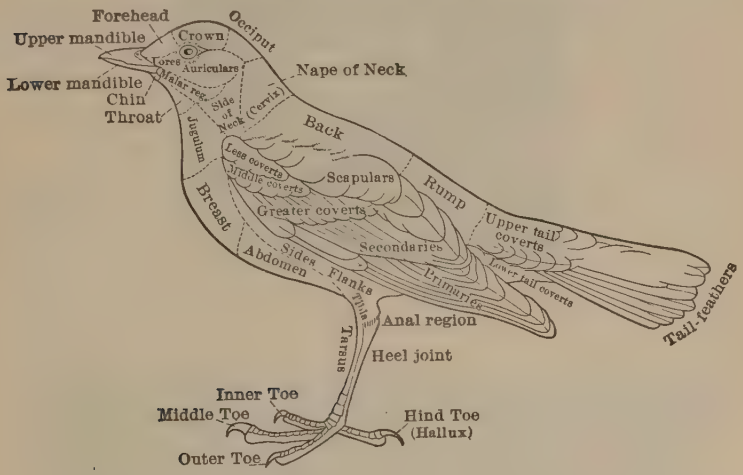

FIGURE 113. — DIAGRAM OF BIRD.

The number of eggs that birds lay in their nests varies from one to as many as thirty or forty. The time required to hatch the eggs varies from ten days to six weeks. Birds

FIGURE 114. — PRAIRIE HORNED LARKS.
First spring arrivals in the North.

whose eggs hatch in ten days or two weeks are called *altricial* (ăl-trĭ′shal: Latin, *altrix*, nurse), for such young are hatched helpless, blind, and with little down. Eggs that hatch in

FIGURE 115. — NEST OF GOLDFINCH.
An altricial nest.

FIGURE 116. — EGGS OF THE WOODCOCK.

The nest is merely a depression in the leaves with no lining. The young leave the nest within a few hours after hatching, so that a nest to hold the young would be useless. Young that leave the nest soon after hatching are called præcocial.

from three to six weeks develop well-formed young, able to run around within ten to twelve hours after hatching. These are known as *præcocial* (pre-kō′shal: Latin, *prae*, before; *coquere*, ripen). Such birds have little need for a substantial nest and only a few of them build one. The robin is altricial, and the domestic fowl præcocial (Figures 115 and 116).

STUDY OF BIRDS

Study of a Living Bird

Have a member of the class bring a canary or other caged bird to school for observation. Questions about the bird may be asked and answered by members of the class. The following are typical questions that may be used:

1. How many toes has the bird?
2. Are these toes grouped, two in front and two behind, or three in front and one behind?
3. Are the toe nails long or short? Are they used for taking food, for holding food, for perching, or for what?
4. How are the feathers distributed?
5. Where are the long feathers? The short feathers?
6. Does the bird walk or hop?
7. Are the feathers evenly colored? Examine the molted feathers in the cage.
8. Examine the beak. Is it adapted for crushing seed, tearing flesh, catching insects, drilling, etc.?
9. Examine the feet. Are they adapted for tearing flesh, scratching, wading, etc.?
10. Examine the eyes. Does the bird wink?
11. Does the bird have eyelashes? Describe them, if any are found.
12. Can you find a third eyelid? Describe it if found.
13. What are the colors of the head, back, tail, breast, throat?
14. Are there any special markings, such as head bands,

shield spots, splashes of color, or any other striking color features?

15. How many kinds of sound does the bird make, such as different songs, alarm notes, call notes, etc.?
16. How does the bird drink?
17. How does the bird eat?
18. What and how much does it eat?
19. How does the bird bathe?
20. How does the bird "dust"?

147. Economic Importance of Birds. — The chief food of some birds is insects and in this they are beneficial to man for they kill the insect pests that destroy the crops especially in the South and West. Other birds, however, that eat the food needed by man, or that destroy the small and more useful birds, may be termed harmful.

Beneficial Birds. — Birds such as quails, crows, red-winged blackbirds, kingbirds, shrikes, bluebirds, blue jays, pheasants, and many others feed on grasshoppers. Army worms which are harmful, almost without exception, are food for quails, vesper-sparrows, song-sparrows, and pheasants. The flicker eats ants by the thousands. Cuckoos are the enemies of caterpillars and canker worms.

Among the hawks and owls are found many beneficial birds, for the screech owls, red-tailed hawks, red-shouldered hawks, together with shrikes destroy such harmful rodents as mice, shrews, moles, prairie dogs, woodchucks, and rabbits. The hawks prey upon them during the day and at night the owls continue the slaughter. The shrikes feed upon mice to a great extent.

Doctor A. K. Fisher gives an interesting illustration of the work done by a pair of owls that lived in the Smithsonian Institution at Washington. He found in examining the pellets that were scattered about their roosting place 450 skulls of small animals, of which 250 were meadow mice.

Aside from their value in destroying insects, birds are valuable as scavengers. The buzzards and vultures of the South and West eat dead animals. The gulls of the sea

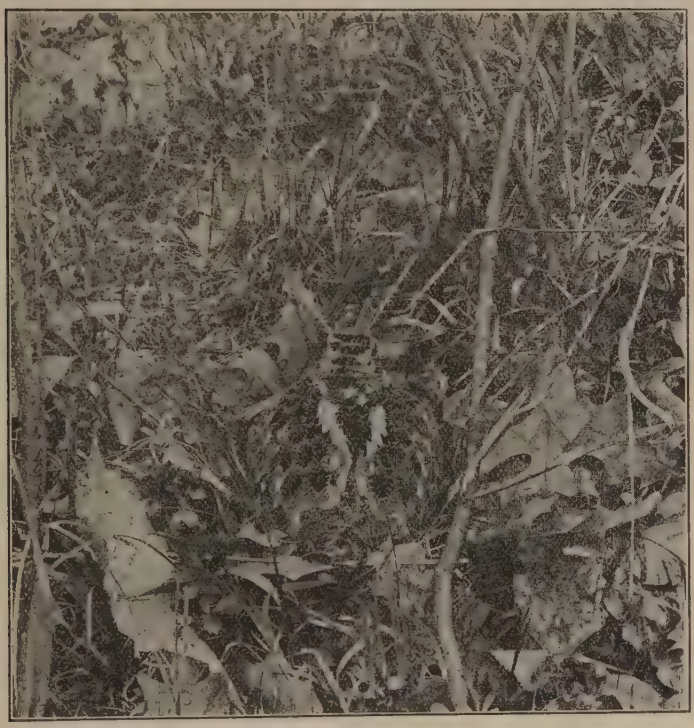

FIGURE 117. — WOODCOCK ON NEST (incubating).

This is an example of protective coloration. The pattern of the sitting bird blends with the surroundings so that it is difficult to see the bird as long as she remains quiet. Note that this bird can see directly behind her without turning her head. The eyes are placed well back in the head. This is an adaptive feature and serves to protect her.

and lakes destroy refuse thrown upon the water. The eagle eats the dead fish that float on the surface of the water, or small dead animals lying in the open on the land. Crows also eat dead fish.

There is a group of birds that lives largely on seed and these birds, for example the tree-sparrow, red polls, song-sparrows, juncos, pheasants, and quails, destroy tons of weed seed during the fall, winter, and spring. In doing this they have a distinct value to agriculture.

FIGURE 118. — NEST OF CHIPPING SPARROW WITH COWBIRD'S EGG.

Harmful Birds. — Not all birds are beneficial to man. Some birds are beneficial a part of the year, and more or less harmful at other times. Whenever the taste of a bird is like our own, they take our foods. For example, a robin will eat cherries and berries which we are raising for ourselves.

Some of the smaller hawks, such as the sharp-shinned hawk and cooper hawk, are fond of small insect-eating birds and the young of our domestic fowls. This classes them as harmful. The house (English) sparrow is likewise in bad repute because of its attitude towards more useful birds.

It uses the nesting places and even the roosting places of more beneficial birds and thus drives them away. In addition, the house sparrows are noisy and generally annoying, but they seem to be here to stay as it is practically impossible to exterminate them.

FIGURE 119. — MALE AND FEMALE COWBIRDS.

Notice the difference in shade of the two birds. The female at the right is gray. What advantage would a dull color be to her while she was in the nest of another bird?

148. Necessity and Methods of Bird Protection. — As the population increases it encroaches on the forest areas, waste land, and other favored nesting sites of birds. To prevent the extermination of desirable birds, we must protect them against the losses caused by advancing civilization. The available agencies for this work of conservation may be divided into three classes: (1) National, (2) State, and (3) private.

Work of the Government. — The government of the United States has passed laws that have greatly aided conservation.

The Lacey law as amended in 1909 prevents the shipping of birds from a state where it is illegal to kill them.

The Weeks-McLean law passed in 1913 gave authority to certain departments to extend better protection to migratory game birds and insect-eating birds. A closed season is provided for ducks, geese, swans, rails, sandpipers, and others. Thrushes, orioles, swallows, wrens, woodpeckers are always protected and cannot be taken at any season. For example, the robin, which is a thrush, must not be killed anywhere in the United States under any circumstances. A state law making an open season on robins would be a violation of the federal law.

In the case of the Weeks-McLean law there is a double protection, for even though it should be declared unconstitutional by a court its provisions are secured by a treaty between the United States, Canada, and Great Britain.

Another aid to conservation is a section of the tariff act of 1919 by which " the importation of aigrettes, egret plumes or so-called osprey plumes and the feathers, quills, heads, wings, tails, skins, or parts of skins of wild birds, either raw or manufactured and not for scientific or educational purposes is hereby prohibited. This act does not apply to ostrich feathers or feathers or plumes of domestic fowls."

Work of the States. — Besides the national protection which the birds are given each state has the power to extend additional protection through laws which aid in the propagation of birds.

New York has a splendid conservation law on its books, known as the Bayne-Blauvelt law. This law forbids the sale of all native wild game birds in New York State no matter where they are taken. This is a distinct advance over the Lacy law. How?

Most of the states have special officers to enforce the game laws.

The laws passed by the national government and the vari-

John James Audubon (1780–1851), self-trained naturalist, supported his family by drawing portraits. His father was a French naval officer and his mother partly Spanish. He spent a few years in France where he gave his main energy to music, drawing, and natural history during the period when he was in training for the navy.

After his return to America about 1800, he became a wandering naturalist, ever seeking for new birds to study. As he went from place to place, he would pay for his lodgings or a new pair of shoes by making a portrait of some local celebrity or even the shoemaker himself.

His most famous work consists of one thousand and sixty-five natural sized, colored figures of American birds, the publication of which alone took ten years and cost $100,000. Whenever you visit a large library, ask to be shown Audubon's Birds, the most noted book on American birds.

ous states have originated and have been pushed by organizations of citizens interested in conservation.

Work of Private Organizations. — The National Association of Audubon Societies is one of the most energetic and powerful of these organizations. It was founded in 1902 and in 1906 was endowed to the extent of $322,000. It now has an annual income of more than $70,000, which is expended in education, propagation of birds, and in the protection of various bird refuges throughout the United States. This organization is a monument to its founder, William Dutcher.

The American Ornithologists' Union is a national organization, composed primarily of bird students. Most of the ornithologists of the country are members. They study problems pertaining to birds, for example, their distribution, migration, economic importance, etc. The *Auk*, a quarterly magazine contains the latest facts and news items on birds. A committee from this union drafted the so-called Audubon law in 1886. This law legally defines game birds, gives protection to useful non-game birds and provides for permits to be issued to bird students for the purpose of collecting birds for scientific study. It is now in force in nearly all the states of the Union.

Work of Individuals. — While the government at Washington and the various states at their capitals may pass conservation laws, it is public sentiment that compels their enforcement. In other words it goes back to the individual to do his part in supporting and respecting the various laws.

Some individuals of means have purchased lands suitable for breeding grounds, where ample protection is afforded either by state officials or privately hired protectors.

The Ward-McIlheny Bird Preserve of 13,000 acres in Louisiana is an example of such an area. Here thousands of ducks, geese, herons, and egrets are allowed to breed and to feed without being disturbed in any way.

Marsh Island Preserve was made possible by a gift of $150,000 by Mrs. Russell Sage. This island is close to the Ward-McIlheny Bird Preserve and gives additional protection over a wider area.

National Game Preserves and Bird Refuges. — Yellowstone National Park contains more then 2,000,000 acres. This is a famous game preserve and all animals are protected there. Glacier National Park contains over 800,000 acres. The Witchita National Game Preserve in Oklahoma contains 57,000 acres. Yosemite National Park in California contains 719,000 acres. No hunting is allowed in any of the parks and preserves.

FIGURE 120. — BLUEBIRD.

Throughout the United States including Alaska and various islands in the Atlantic and Pacific, there are more than 100 other bird refuges and game preserves.

State Parks and Game Preserves. — In Pennsylvania several of the counties have game preserves containing 2,000 or 3,000 acres each. In New York State there is the large Adirondack State Park which contains more than 1,500,000 acres in the northern part of the state. In the southwestern part is located Allegheny State Park, which contains more than 7,000 acres. There is also the Palisade Park, Letchworth Park, and many other smaller ones scattered through the state. In Wyoming, the Teton State Preserve which adjoins the Yellowstone National Park contains 576,000 acres. In Louisiana there

is a state Wild Fowl Refuge on Vermillion Bay of 13,000 acres which joins the Ward-McIlheny tract.

149. Recognition of Common Birds. — In most of the states of the Union, there are probably between 200 and 500 kinds of birds found during the year. California with its great extent from north to south and its varied topography offers the greatest variety of environments of any state in the Union. No doubt, it leads in the numbers of birds found there. More than 500 have been identified in this state. In New York State not more than half that number have been recorded.

FIGURE 121. — CATBIRD.

We may select from these large lists certain representative birds for study.

Bluebird. The *bluebird* is found in yards, on the roadsides, and in second-growth woods throughout the greater part of the United States. It is about seven inches long. The upper part of the male, including wings and tail, is bright blue. The breast and throat are cinnamon color. The female is grayish blue above and paler than the male below. This bird nests in holes in trees and fence posts and is readily attracted by nesting boxes put up in orchards and woods. Its food consists of caterpillars, grasshoppers, crickets, and, in cold weather, of some flying insects that are benumbed by the cold.

The Catbird is nearly nine inches long and of a slate-gray color. The crown and tail are black. This bird is friendly

and builds its nest near human habitations quite as often as in the woods. Catbirds are merely summer residents in the North, arriving latest in the spring and leaving earliest in the fall. They devour large numbers of insects and sometimes take berries and cherries. This privilege they have earned by their services in destroying insects. They are fine musicians and clever mimics, and are often called the mocking birds of the North.

The Crow. "Black as a crow" is sufficiently accurate for a color description. Crows have bluish and purplish

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FIGURE 122. — CROW FEEDING ON FISH AND CORN.

lights on their black feathers. A mature crow is nearly twenty inches long. They are usually classed as permanent residents in the Northern States. It is quite likely however, that the crows that nest in Northern States go South in the winter and their places are taken by winter visitants from Canada. These winter crows usually roost together in rookeries where thousands are sometimes seen. They live in the deep woods, roadsides, orchards, and parks. They feed upon grass-

hoppers and other insects, and young birds. They have been known to eat the eggs of some of our valuable song birds. The crow, therefore, is partly helpful and partly harmful.

FIGURE 123. — CHICKADEE.

The Chickadee is only $5\frac{1}{2}$ inches long but its great activity makes it valuable out of proportion to its size. It eats the eggs, larvæ, the pupæ, and the adults of a long list of insects. Being a permanent resident within its range, it does most effective work every month of the year. The bird is attractively marked with black and white. The top of the head has a black cap. It comes to the yards and orchards freely in the winter time where its spirited notes of "Chickadee-dee-dee-dee" make it a conspicuous visitor. It nests in a hole of a tree or stump and sometimes in a nesting box.

FIGURE 124. — BALTIMORE ORIOLE.

The Baltimore Oriole is about $7\frac{1}{2}$ inches long and is very noticeable because of its plumage. The colors are black and orange, striking in the male but duller in the female. The head, neck, and back are black while the lower back and under parts are rich orange. The tail is

orange and black. The bird is almost wholly limited to roadsides, villages, and parks where it builds substantial hanging nests from the branches of elms and maples. It feeds mainly on caterpillars but eats other insects, now and then taking cherries. It is a welcome summer resident in the Northern States.

FIGURE 125. — ROBIN.

Robins are rather large birds, 10 inches in length and rated as summer residents in the North. A few remain over the winter in favorable locations and probably are the so-called early arrivals reported in the spring. Robins are black, gray, and white in color. In the male the top of the head is black. Above and below the eye are white spots. The tail is dark with the tips of the outer tail feathers white. The females are of lighter color. Robins are found widely scattered in yards and orchards, along the roadside, in the parks, and the second-growth woods. Usually two broods are raised each season. They feed upon caterpillars, crickets, and other insects. They also eat earthworms. In some regions they are unpopular because they eat the smaller fruits but this damage they more than pay for by destroying insects.

FIGURE 126. — HOUSE SPARROW.

The House (English) Sparrow like its European cousin, the Starling, is an imported product, brought over from England about 1851 for the purpose of destroying certain insects. It has now spread to the Pacific coast. There is reason to believe that in time the bird will become a valuable addition to our bird life. It now feeds on many weed seeds and destroys such insects as the cut worms, tussock moths,

Photograph by Dr. G. S. Britton.

FIGURE 127. — DOWNY WOODPECKER AND SONG SPARROW.

some weevils, cabbage worms, and white grubs. The male has a gray crown while the back is streaked with black and chestnut. A part of the throat and breast is black while the under parts are whitish. The bird is a little more than 6 inches long. The chief fault found with this bird is that it uses the nesting sites of other more desirable birds and as a result these exiled birds are driven away.

The Downy Woodpecker is the best known and the smallest of all woodpeckers in the United States. The principal

markings are in black and white. The adult male has a scarlet band on the nape of the neck while the female lacks this mark. The under parts are white and there is a white stripe above the eye and another below it. In the winter season the downy woodpecker becomes a frequenter of our orchards and yards cleaning the trees of insects. He is also often found in the woods. Being a permanent resident, he renders a 365-day service. Every day in the year he must procure food enough to support his active body and by so doing he renders an important service to us. Some one has remarked that each of these birds is worth $10, measured by the good they do.

FIGURE 128. — BARN SWALLOW.

The Song Sparrow is a permanent resident in the Northern states. It is widely distributed in North America and shows great variation in color and size throughout the continent. It is usually a little more than 6 inches long and is a valuable bird because it destroys weed seeds and various insects. It keeps to the lower levels and frequents brush lands, hedges, and marshes. Occasionally it nests in holes of trees. More frequently, however, it nests in the grass or shrubs along ravines, brooks, hedgerows, and open fields. It is generally gray and brown in color. Its breast has wedge-shaped streaks of black and brown with a large blotch in the center.

The Barn Swallow is nearly 7 inches long. Its food is exclusively flying insects which it gets close to the ground. Unlike other fliers it seems to skim the ponds and roadways for its main supply of food. It is known to feed on grasshoppers, flies, gnats, and mosquitoes. The lower parts are chestnut color and the upper part steel blue. The tail is deeply forked. This is a summer resident and its stay in the North is brief. The nest which is made of mud and lined with feathers, is usually placed on the rafters of old barns, sheds, or granaries.

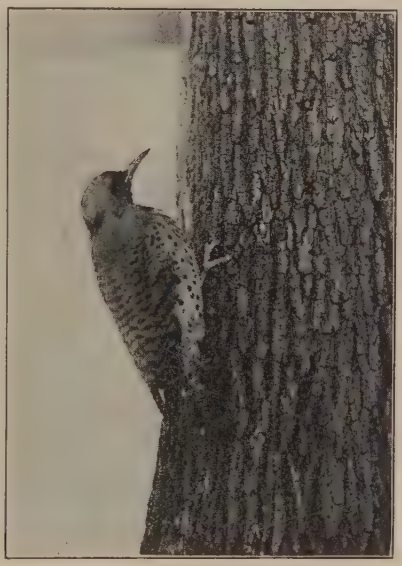


FIGURE 129. — FLICKER.

The Flicker is a large woodpecker about 12 inches long and is classed as a summer resident in the North. Equally at home in the woods or on the lawns, it has come to have a wide circle of acquaintances. No other bird has so many aliases. More than a hundred other names have been given it, of which the commonest are yellow hammer, yarup, and golden-winged woodpecker. Its colors are striking. There is a scarlet band across the neck and a black crescent on its breast. The under parts are white, thickly spotted with black. The upper parts are gray barred with black. Its food consists largely of ants but it feeds also on wood borers, like other woodpeckers. As many as 3,000 ants have been found in the stomach of one flicker.

The Goldfinch is a permanent resident that is seldom seen in the winter. The bird is about 5 inches long and its striking colors of gold and black make the male conspicuous as he feeds in gardens and lawns. The brilliant dress of summer is lost in the winter time and the duller colors that succeed it make the bird less easily recognized. Another reason for their being seldom seen in the winter is that these birds go in flocks and keep to the swamps and woodlands. Nest building is delayed until June or July in the North. The principal foods of goldfinches are seeds of thistles, dandelions, and wild sunflowers. They also eat the seeds of cultivated sunflowers.

FIGURE 130 — PHOEBE.

The Phoebe is due in the Northern States when the pussy-willows show their fuzzy blossoms. This summer resident is dull colored and its note is all that gives it fame. The colors are grayish brown above and white or yellowish below. It bears distinct wing bars. Now and then conservative individuals build nests on ledges and overhanging banks but for the most part their nests are built on man-made structures such as houses, barns, sheds, bridges, trestles, and viaducts. The phoebe is a fly catcher and for this reason man needs to encourage its presence. Among the insects it catches may be mentioned the click beetles, weevils, and numerous kinds of flies and moths. The nests are frequently overrun with lice to such an extent that the young are killed.

The Herring Gull is a water bird. It nests on islands and the shore of the mainland and gets its food largely from the water. Our inland streams and lakes are frequented in certain seasons by these birds. As its name indicates it feeds on fish but it is not limited to that diet. Gulls are scavengers and they are found in large numbers near garbage dumps. In the lower harbor of New York Bay, gulls follow

FIGURE 131. — HERRING GULLS.

the scows which are carrying garbage. Mr. Frank M. Chaplin estimates the number he saw here at one time as three hundred thousand. The herring gull is 24 inches long. The colors of the male in summer are deep pearl gray and white with spots of black. In winter, the male has many spots of gray.

The Screech Owl is one of our smallest owls having a length of only 9½ inches. The bird has two color phases, a rufous and a gray. In the former phase the colors are rufous above

with streaks of black and white below. In the gray phase the rufous is replaced by gray. These color phases do not depend on age, sex, or season. There are many gradations between the two phases. Screech owls are permanent residents and mostly beneficial as they feed largely on mice and insects. They sometimes eat earthworms. During the day they rest in hollow trees, conifers, old buildings, and caves. They also nest in hollow trees or bird boxes.

FIGURE 132. — SCREECH OWL.

The Yellow Warbler is one of our smallest warblers and measures about 5 inches in length. The male is greenish yellow above and bright yellow beneath. The lower parts are streaked with rufous. It courts man's company and keeps well to the yards, gardens, and roadsides. The nest is compactly built of fine grass and fibers and lined with plant down or hair. It is a summer resident. This bird is frequently victimized by the parasitic cowbird. The eggs of the cowbird are sometimes buried beneath another nest which the yellow warbler builds in an effort to avoid hatching a cowbird's egg.

Wrens. — There are some 150 kinds of wrens known to science. These are found mostly in the tropics, only about one dozen species occurring in the United States. They frequent stubby growths and bushes. The house wren is 5 inches long. The upper part is brownish, the back gener-

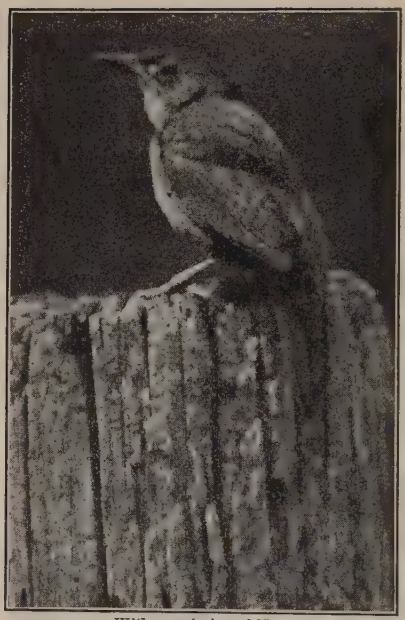
ally has indistinct bars, the wings and tail are finely barred, and the under parts of the body are whitish with numerous blackish bars on the sides. It breeds as far north as Manitoba and winters in the South. In our climate they are nearly always found around dwellings and when they become attached to a nest return year after year. They are one of the friendliest birds and most easy to attract to our homes.

150. Adaptations of Birds. — The front legs of birds are modified into wings. Among some birds, like the *penguins* (pēn′gwĭnz) of the Antarctic region, the wings are not used for flying but to assist in swimming. In others, like the eagles and condors, the expanse of the wings is sufficient to enable them to fly away with young lambs and large fish. Between the small wings of the penguin and the expanse of the wings of the eagle and condor there are many variations.

Photograph by Dr. G. S. Britton.

FIGURE 133. — YELLOW WARBLER.

Bird wings are adapted to the needs of their owners. Sailing birds, like the gulls, have long, slender wings, while ground birds, like the partridge and pheasant, have short wings capable of rapid, short flights. Those birds that make the most use of wings have them best developed. An example of underdevelopment, which has been increased by



With permission of Nature Magazine.

FIGURE 134. — HOUSE WREN.

domestication, is seen in the domestic fowl, a ground bird, which makes little use of its flying powers, and is incapable of sustained flight.

The legs of birds also have many variations. In the case of the eagles, hawks, and owls there are powerful claws for seizing and holding prey, while ducks and geese have long and webbed toes, adapted to swimming. Seed-eating birds have weak toes which serve merely for perching. Chimney swifts, that spend most of their time in flight searching for food, have well developed wings, and feet used for clinging. Study Figure 137.

The beaks of birds show great variation and adaptation for defense and food-getting. Hawks, owls, and eagles have the upper jaw curved over, hooked, and adapted for tearing their food; herons and bitterns have the beak modified into a long, pointed weapon of offense and defense; grosbeaks (grōs′bēks)

FIGURE 135. — KINGFISHER.
A fish-eating bird.

and finches have a short, stout beak for crushing seeds and other hard foods; while humming birds have a long, slender beak which in some kinds is curved so that they may reach the bottom of certain flowers. Study Figures 118, 129, 135, and 138.

FIGURE 136. — JUNCO.
A seed-eating bird.

The birds show a number of other interesting adaptations which are of use to them. These are hollow bones, a keeled *sternum* (breastbone), and a high body temperature.

The skeleton of a bird shows a prominent ridge on the breastbone. This is the keel of the sternum, which serves as a place of attachment for the large wing muscles (Figure 139). The lungs of the bird are small, but air tubes extend into the bones, so that the body of the bird is relatively lighter than that of animals with solid bones.

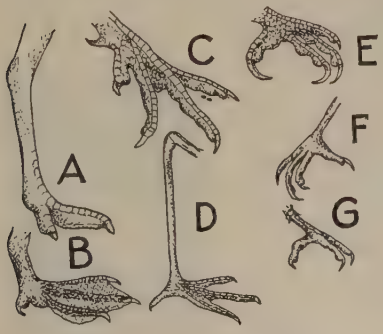


FIGURE 137. — BIRDS' FEET.

A, Ostrich's foot — adapted for running; *B*, duck's foot — adapted for swimming; *C*, hen's foot — adapted for scratching; *D*, plover's foot — adapted for wading; *E*, hawk's foot — adapted for tearing; *F*, crow's foot — adapted for perching; *G*, woodpecker's foot — adapted for climbing.

Birds lead an active life, which means that they use a great deal of energy. This energy comes from the oxidation going on in the body. In birds, oxidation is more rapid than in other vertebrates, owing to the fact that they almost completely change the air

with each breathing movement and thus secure a greater supply of oxygen. The rapid oxidation requires that a large supply of food be digested and assimilated rapidly and it makes the normal body temperature of birds higher than that of other vertebrates.

FIGURE 138. — ROSE-BREASTED GROSBEAK.

Plumage. — Birds are the only vertebrates having feathers, and their plumage shows great variety in form and color. In some species there are certain colors which always predominate on the males, while the females have little color; in other species it is hard to distinguish between the sexes. The brilliantly colored males are supposed to attract the females at the mating season, while the dull-colored females are inconspicuous and less likely to be attacked by enemies while hatching their eggs, or caring for their young. We may say, therefore, that they are protectively colored. The color of birds varies during the first two or three years of life.

FIGURE 139. — SKELETON OF A MALLARD DUCK.

151. Migration of Birds. — Many strange ideas have been entertained about bird migration. At one time it was thought that some birds migrated to the moon. Some thought that one kind of bird changed into another kind. The European cuckoo was said to change into a hawk. Swallows and swifts were thought to go into the mud with the frog to pass the winter. In recent years more attention

has been paid to this subject. Records have been kept, and the bird students of different continents have compared their discoveries. At the present time the movements of practically all of our birds are known. Some of the flights that our birds make are almost beyond belief. For example, the golden plover, which nests on the shores of the Arctic Ocean, winters in Argentina, 8,000 miles away. The Arctic tern may travel 11,000 miles between its winter and summer homes. The black poll warbler flys 7,000 miles to the place where it rears its young. The Baltimore oriole winters in Central America, while the bobolink winters in Brazil. The red-eyed vireo and kingbird spend the winter in Bolivia, and the yellow warbler in Peru. At least one of our North American birds, the wheatear, which nests in the Arctic regions, passes the winter in West Africa, migrating through the British Isles.

Photographed by Abril Cahn.

FIGURE 140. — YOUNG PELICAN.
A fish-eating bird.

The recent studies of starlings are very suggestive in explaining a possible origin of the migration habit in birds. The English starlings of the Northern States, after more than 30 years of residence, have finally learned to migrate. Huge flocks of these birds now go South in the fall, and return with the coming spring. They may truly be said

FIGURE 141. — CANADIAN WILD GEESE.
Photographed while migrating to their northern breeding grounds.

to have been naturalized. Until recently, through sheer ignorance, they have had to adapt themselves to a climate wholly unnatural in its severity, for at home in northern Europe the species migrates regularly to southern Europe, and even to northern Africa, it is said.

Many of them have managed ordinarily to survive even the rigors of the New England winter, but only because they possessed much resourcefulness in snatching a living under most adverse circumstances. Many of them are still ignorant of the milder

FIGURE 142. — RING-NECKED PLOVER.
Seen in New York State only during May and August.

climate southward, in a land where food is plenty, and persist in making their night winter quarters in the belfries of the steeples of cities and towns or more rarely in a country barn.

The starling has been a resident of the United States since about 1890, when half a hundred of them were released in

Photographed by Abril Cahn.

FIGURE 143. — PELICAN FEEDING YOUNG.

Central Park, New York. They multiplied rapidly, and drifted into the surrounding country, and, as years passed, spread farther and farther into the country, until now they are common all through the East and the Central States. Their first knowledge of migration, ornithologists believe,

probably came from their contact with the flocks of blackbirds and bronze and purple grackles, with which latter species they are confused by many people, though they are easily distinguished by their yellow bills. They mingled with flocks of these and other species, and doubtless began to drift southward with them in the fall and back again in the spring.

Photographed by Parke Struthers.

FIGURE 144. — COMMON BOOBY, YOUNG AND ADULT.
A fish-eating tropical sea bird which nests in isolated islands.

How Do Birds Find Their Way? — The long distances that birds fly, the unerring course they follow, and the regularity of their appearance — all lead us to ask: How is it done?

The senses of birds are like our own. They see, they feel, they hear, they smell and taste. But these senses do not seem adequate to account for all they do.

In theory, we assume that it must be done by other senses than those we have mentioned. They must have an unusual sense of direction and the instinct known as the homing instinct developed to a high degree.

At certain seasons of the year an impulse from within arouses the homing instinct and they start for the place where they were hatched and reared. It may be east, or west or in the tropics. It may be north, northeast, northwest, or south. In addition they are guided by a sense of direction.

Experiments have been performed by Professor Watson of the Johns Hopkins University which prove that birds have this sense of direction to a remarkable degree.

152. Methods of Attracting Birds. — For the purpose of study and of appreciation, it is advantageous to bring the birds near the windows of a home, where we may look upon them at odd times and study them at close range. There are several ways of getting the birds to come near a building. A common method is by feeding them. Foods such as suet, bread crumbs, hemp, canary seed, sunflower seeds, and raisins are attractive to birds. They should be so placed that cats cannot strike down the birds while they are feeding. Unless some care is exercised in selecting these feeding places, the birds will be lured into the claws of the ever waiting cat.

Suet may be placed on the side of a tree trunk three or four feet from the ground in a wire loop or in a hole bored in the tree. Bird seed and crumbs may be placed on the ground, but a better method is to put the seeds and crumbs in a box, with a cover a few inches above to keep out the snow. This box should be placed on a post or on the side of a tree trunk a few feet from the ground. Food placed on the ground is likely to be eaten by stray dogs or cats, and in the winter time it will be buried by the snow. Sunflower heads may be hung from the sides of a tree trunk or put on the end of a post.

During the winter the chickadee, white-breasted nuthatch, downy woodpecker, hairy woodpecker, red-headed woodpecker, brown creeper, flicker, and many other birds may come to the suet. Juncos, tree-sparrows, house-sparrows, pheasants, crossbills, evening grosbeaks, song-sparrows, and prairie horned larks will come to the bird seed and crumbs. Sunflower seeds will attract chickadees, house-sparrows, crossbills, goldfinches, and evening grosbeaks.

FIGURE 145. — BIRD PHOTOGRAPHY.
A photographic outfit for taking pictures of birds.

Nesting Boxes. — The putting up of nesting boxes in the yards is another way of attracting birds. In locating these nesting boxes it is essential to success that the place selected should be safe from cats. Cats will climb to the boxes if they can and strike the birds as they leave the nest. When birds are given a choice between several boxes put up in a small area, they seem to select those that afford them the best protection from their enemies. Boxes put up on the ends of posts and away from trees seem to be preferred to those put up in the trees. Poles and posts may be covered with tin or sheet iron to keep the cat from climbing them.

The size of the opening and the inside space determine what birds will be likely to use the boxes. The table at the end of this chapter (see page 204) will give an idea

of the size of the opening and the cavity and locations that are considered proper for some of our town birds.

Bird Baths. — During the dry weather of July and August, the supply of water is greatly reduced. Sometimes the water that is available is in a place where the birds have no chance of escaping a cat that is lying in wait for them. A shallow plate of water placed on a stump or post in the shade is frequently used by the birds. Sometimes a dozen or more kinds of birds will come to these drinking places. At one such bath the following birds came during one summer: robin, oriole, catbird, yellow warbler, song-sparrow, pewee (to catch insects at the water), red-headed woodpecker, black-throated blue warbler, and goldfinch. Birds will bathe in drinking fountains if they are shallow enough to allow them to wade.

FIGURE 146. — NEST OF THE YELLOW WARBLER IN WHICH A COWBIRD'S EGG HAS BEEN LAID.

The warbler first built the nest at the bottom. When this nest received a cowbird egg, a second nest was built on top. Again it was visited by a cowbird and a third nest was made. When the cowbird egg hatches, the young is larger and grows faster than the small warblers. After a time this large bird crowds the small warblers out of the nest and they die. What should you do when you find an egg of a cowbird in a warbler's nest? From Zoölogical Museum, University of Minnesota.

153. Public Museums. — As man came to occupy the land, the forests were cleared away and the ground used to produce food for man and domestic animals. This tended to drive the wild life, native to such regions, into the mountain fastnesses, where they were free to live. This resulted in many of them becoming extinct even when they were of great use to man. The bison and brook-trout are two good examples (Figure 85). The expense of collecting and properly housing the preserved skins and skeletons of such animals is beyond the means of most people. The public museum is the proper place for all such collections, as it is much better to have a few specimens which can be seen by all than to have many specimens in private collections. The men in charge of museums never indulge in useless slaughter, as is so frequently done by hunters.

Every student in such a course as this should plan to visit the public museum or zoölogical park or botanical garden in his city as the different parts of the course are taken up. Pictures and drawings can never take the place of seeing the actual specimens. Going to the museum is like going into the laboratory for first-hand study of the facts. It is studying nature as she is.

TABLE — SIZE OF NESTING BOXES

Bird	Diameter of Opening	Size of Cavity	Location
Chickadee	$1\frac{1}{8}''$	4×4	In protected spots
House wren	$1\frac{1}{8}''$	4×4	Trees and arbors
Nuthatch	$1\frac{1}{4}''$	5×6	On buildings or trees
Bluebird	$1\frac{1}{4}''$	5×6	On buildings or trees
Tree-swallows	$1\frac{1}{4}''$	5×6	In trees near ponds
Red-headed woodpecker	$2\frac{1}{2}''$	6×7	On posts or trees
Flicker	$3''$	6×8	On posts or trees
Wood-duck	$6''$	10×18	Trees or stumps

OUTLINE

- Classification of birds
  - By structure
    - Raptores
  - By migratory habits
    - Wild geese
  - By nesting habits
    - In fields
      - Meadow lark
    - In trees
      - Hawks
      - Orioles
    - In sand
      - Kingfisher
- Nests: Building
  - Altricial
    - Robin
  - Precocial
    - Domestic fowl
- Economic importance
  - Beneficial
    - Quail
    - Bluebirds
  - Harmful
    - Cooper hawk
    - House sparrow
- Bird protection
  - Federal government
    - National preserves
  - State government
    - State parks
  - Private organization
  - Individuals
- Recognition of common birds
  - Bluebird
  - Catbird
  - Crow
  - Chickadee
  - Oriole
  - Robin
  - Sparrow
  - Downy woodpecker
  - Song sparrow
  - Barn swallow
  - Flicker
  - Goldfinch
  - Phœbe
  - Herring gull
  - Screech owl
  - Yellow warbler
  - Wren
- Adaptation of birds
  - Wings
    - Penguin
    - Gull
    - Pheasant
  - Legs and feet
    - For seizing
    - For perching
  - Beaks
    - Curved for tearing
    - Sharp for pecking
    - Stout for crushing
  - Breastbone
    - For attaching wings
  - Plumage
    - Males brilliant
    - Females protected by color
- Migration of birds
  - Distances traveled
    - Golden plover
    - Arctic tern
    - Starling
  - Sense of direction
- Attracting birds
  - Feeding
  - Nesting boxes
  - Bird baths
- Public museums

SUMMARY

Birds are classified according to their structure and also according to their migratory and nesting habits. They are of enormous economic value, chiefly because of the large number of insects they destroy. For this reason the government protects them and they are also taken care of by private organizations and individuals. Bird study is a fascinating subject and a great deal of pleasure may be derived from the ability to recognize common birds.

Birds are peculiarly adapted to the work they have to do. Their wings, legs, feet and beaks vary according to their mode of life and the kinds of food they live on. The brilliant plumage of the male is supposed to attract the female during the mating season, while the duller feathers of the female afford protective coloration, when nesting and caring for the young.

Birds migrate with the seasons, sometimes going thousands of miles. Some winter with us, spending the summer farther north. Others are here in the summer and go south for the winter. It is pleasant to get them to stay with us, for they are delightful companions. This may be done chiefly by feeding, and also by putting up nesting boxes and arranging bird baths.

QUESTIONS

In what ways are birds classified? How are they economically important to man? In what ways and by what agencies are they protected? How many common birds can you recognize by sight? Name them. What are the different adaptations of birds? For what purposes is the beak used? The claw? The wings of a penguin? What are the advantages and disadvantages of the plumage of the average male bird? Of the female? Why do birds migrate? What birds go north in summer? Which ones go south in winter? Do you know any that spend the year here? What summer bird do you usually see earliest in the spring? What are the best ways of attracting birds? Have you ever tried any of them?

CHAPTER XIV

MAMMALS, THE PRESENT RULERS OF THE UNIVERSE

A righteous man regardeth the life of his beast.
— PROVERBS, XII, 10

154. Mammals Defined. — When the great reptile animals became extinct in late geological history, the hairy-coated animals took their place as rulers of the animal world. This place they have maintained because they have the best developed brains of all animals. They are warm-blooded (the body temperature remaining the same in winter and in summer), breathe by means of lungs, give birth to young, and are provided with milk glands (*mammæ*, hence the word mammal) to suckle their young. Mammals are covered with hair wholly or in part at some period of their lives. A muscular wall (diaphragm) subdivides the body cavity into two parts. The anterior contains the four-chambered heart and lungs and the posterior contains the stomach, intestines, liver, and other organs. At birth the young resemble the parent in having the same parts.

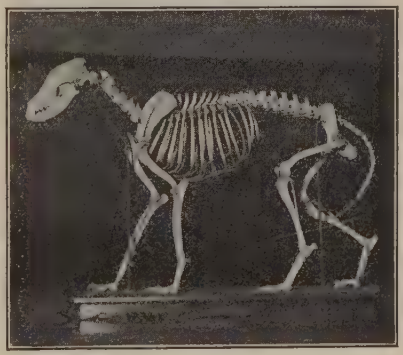
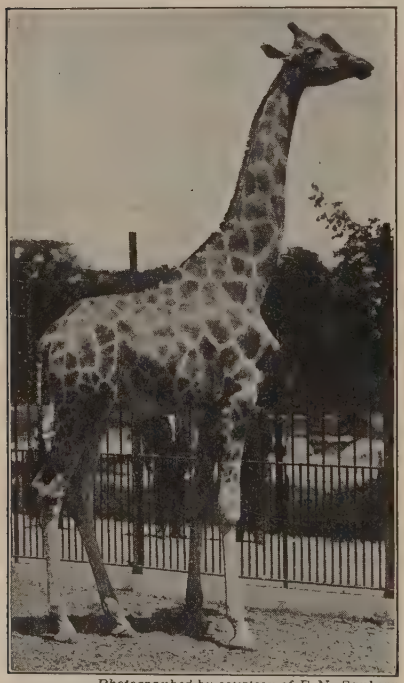


FIGURE 147. — SKELETON OF A DOG.

All the animals that you have studied in this course were able to live because they secured food which nourished their bodies, exercised the function of respiration, excreted waste, were adapted to their environment, and reproduced their kind. You have become so familiar with these life functions that it is necessary only to say that they apply in the same way to mammals.



Photographed by courtesy of E.N. Sanborn.

FIGURE 148. — GIRAFFE.

155. Kinds of Mammals. — There are some 800 different kinds of mammals in New York State, but even this large number does not represent all of the larger groups. The following classification gives you a general idea of most kinds of mammals, to which the names "beasts," "quadrupeds," "animals," are commonly applied. This list is for reference and need not be memorized.

1. Pouched mammals (*Marsupials*), Kangaroo, opossum.
2. Insect-eating mammals (*Insectivora*), Hedgehog, mole, shrew.
3. Flesh-eating mammals (*Carnivora*), Cat, dog, civet, mink, raccoon, bear, seal.
4. Toothless mammals (*Edentata*), Sloth, anteater, antbear.

5. Gnawing mammals (*Rodentia*), Rabbit, squirrel, rat, porcupine, mouse.

6. Hoofed mammals (*Ungulata*), Cattle, deer, giraffe, horse.

7. Trunk mammals (*Proboscidia*), Elephant.

8. Flying mammals (*Chiroptera*), Bat.

9. Mammals adapted to marine life (*Cetacea*), Whale.

10. Mammals with nails (*Primates*), Lemur, monkey, ape, man.

In the following paragraphs the four large orders, Carnivora, Rodents, Ungulates, and Primates are discussed in some detail.

FIGURE 149. — DEER MOUSE.

A nocturnal rodent that is seen moving the wire that set off a flash light and snapped the camera.

Carnivora. — The term Carnivora means "flesh-eating"; in this order we find the canine teeth well developed and the jaws strong. The feet are usually provided with claws which may be withdrawn, as in cats, or which cannot be withdrawn, as in the dog family. There are the aquatic carnivora, sea-lion, walrus, seal; and the land carnivora, which in turn are divided into three well-known groups: (1) bear and raccoon which walk flat-footed; (2) coyote, wolf, tiger, lion, hyena, cat, dog, etc., which walk on their toes only; (3) weasel, otter, skunk, and mink that walk partly on the toes.

Rodents. — The Rodents are the gnawing mammals which have the incisor teeth chisel-shaped and much enlarged. These gnawing teeth of the rodents keep growing so that they are not worn out and they also keep sharp because the front edge is harder than the back. Rodents lack the canine teeth of the carnivora. It is only necessary to name the more common members of this order to realize how very destructive the rodents are, for here are included the rat, mouse, rabbit, porcupine, chipmunk, squirrel, beaver, and woodchuck.

Ungulates. — The Ungulates, commonly known as the hoofed mammals, live on vegetables and thus have the molars, their back teeth, adapted for grinding. Hoofs protect the feet, while the whole limb is specialized for swift locomotion. They are divided into two groups, according to whether they have an even or odd number of toes.

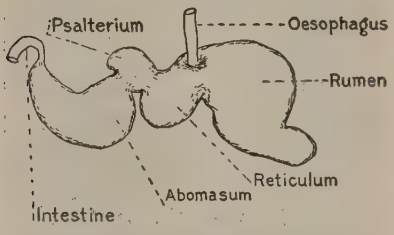


FIGURE 150. — STOMACH OF SHEEP.

1. Odd-toed; horse, tapir, rhinoceros.
2. Even-toed;
   (*a*) the non-ruminants, hippopotamus, pig.
   (*b*) the ruminants, deer, sheep, cow, etc.

The term *ruminant* refers to the habit of chewing the "cud," which really means that the food, hastily swallowed, is forced again into the mouth and thoroughly chewed. Such animals have a specialized stomach (Figure 150).

Primates. — The Primates represent a distinct group of mammals with the brain especially well developed. This is the main reason why we think of the animals in this group as the highest mammals. The lemurs and monkeys are mostly tree-inhabiting animals, with nails in the place of

claws on the fingers and toes. The body is completely hairy. Fore-feet are grasping hands as a rule, and the hind-feet walking as well as grasping.

Our chief interest is in the generally accepted conclusion that this is the place where man as an animal should be classed. In the refinements of classification man is placed in a distinct family, the *Hominidæ*. Here are grouped the interesting extinct races of men as well as all modern races.

FIGURE 151. — FORE-ARM AND HAND OF MOLE.

156. Special Adaptations. — Most mammals have two pairs of limbs; the fore-limb may be variously modified for different uses, as for walking in animals like the horse, for climbing and for food-getting in the squirrel, for burrowing and for locomotion in the moles, for flying in the bats, and for swimming in the seals. In all fore-limbs of mammals even those as different as the leg of the squirrel, the flipper of the whale and seal, and the wing of the bat, the arrangement of the bones is the same.

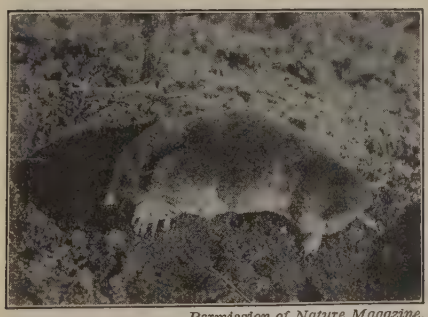


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FIGURE 152. — MOLE.

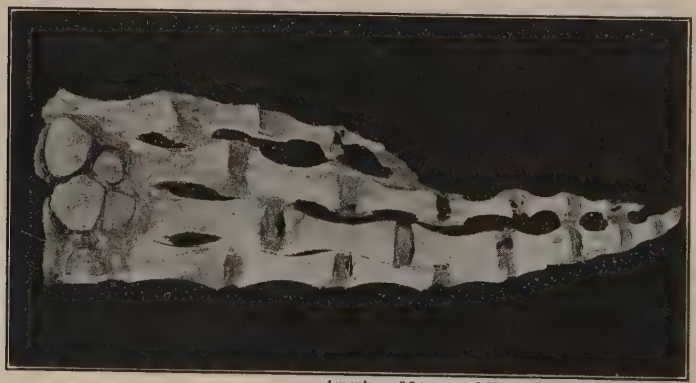
Notice how short the legs are and the large size of the "hand" adapted for digging.

The hind-legs of mammals do not show so much variation as the fore-limbs, but in some cases, as in the whale, the hind-legs have almost disappeared through disuse and there is no external evidence of them. Some animals, like the bears, walk on the soles of their feet, and some, like the cats and the

dogs, walk on their toes only. In some animals there is a variation in the number of the toes; for example, the cow walks on two toes, the horse on one toe, the hoof being a modified toe nail. In such cases the other toes are entirely lacking or rudimentary (not perfectly developed).

FIGURE 153. — ARM (WING) OF BAT.

The skeleton of mammals is built on a similar pattern in all cases. Even apparently marked differences are found, on examination, to be only modifications of similar parts. In the vertebral column (Figure 147) there are several regions, such as neck, rib, back, hip, and tail. It happens that the number of the separate vertebræ in the neck region is the same in the dog, horse, mouse, giraffe, bat, man, etc., but



American Museum of Natural History, New York.

FIGURE 154. — FLIPPER OF BALAENOPTERA BOREALIS.

Note the resemblance to fingers.

the neck region is not of the same length. This is conspicuously evident in the giraffe (Figure 148), but when one examines this very long neck there will be found only the regular seven neck vertebræ. Each of these vertebræ in the neck of the giraffe is very large, and this is an adaptation

that helps the giraffe in securing its food, which consists of the leaves of trees.

Some strange modifications, the pouch of the kangaroo and the trunk of the elephant, should also be mentioned. The kangaroo is one of the simpler animals. The young are helpless at birth and are carried around in a special pouch (Figure 157) until they are able to take care of themselves. The milk glands are located in the pouch so that the young are easily nourished and protected. The trunk of the elephant is composed of the nostrils and upper lip drawn out into a long muscular organ (Figure 159), and is used in bringing food to the mouth. The web of the flying squirrel is another strange adaptation which enables it to sail more easily through the air.

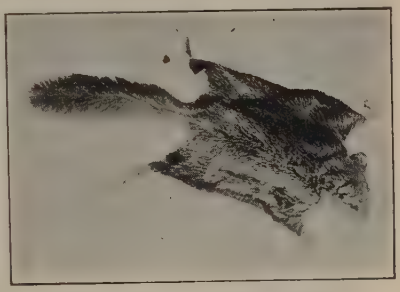
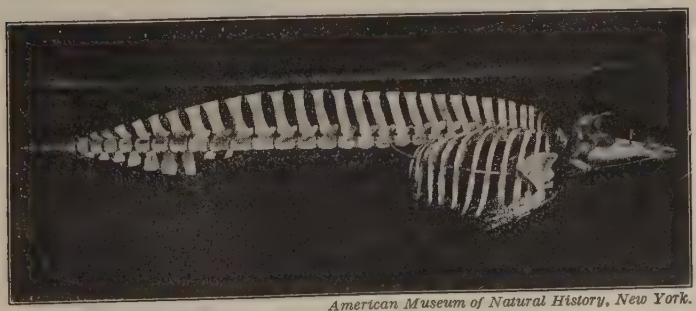


FIGURE 155. — FLYING SQUIRREL.

The skin is stretched between the fore- and hind-legs and acts like a parachute. Does the animal really fly?

157. Adaptations for Protection. — Mammals are found widely distributed over the surface of the earth, living in



American Museum of Natural History, New York.

FIGURE 156. — SKELETON OF ZIPHIOID WHALE.

Photographed by Meyer and Widman.

FIGURE 157. — KANGAROO WITH YOUNG IN POUCH.

the frozen North and the humid tropics or roving over plains and mountains. Everywhere they show adaptations in habits and form.

The color of the white polar bear and Arctic fox renders them inconspicuous against the ice and snow. Deer are among our swiftest runners and the possession of such speed helps them to escape when being chased. In marked contrast to the habits of the deer, when in danger, is that of the opossum (Figure 158) which often rolls up into a ball and

feigns death. After the animal which has been annoying the opossum withdraws, it deliberately and slowly begins to move.

Whales are aquatic mammals that have lost most of their protective coat of hair but have developed instead a thick layer of protective fat beneath the skin. This is whale blubber. The porcupine has its hair enlarged and specialized into spines. These special hairs effectively protect the porcupine from lynx and wildcats when they try to feed on

With permission of Nature Magazine.

FIGURE 158. — AMERICAN OPOSSUM.

it. These spiny hairs, in turn, are in marked contrast to the protective coat of wool of sheep, which is modified hair.

There are as many habits and adaptations for escaping from enemies in mammals as there are for fighting. Burrowing in the ground like the woodchuck, or nesting in the tree like the squirrel, protects the young as effectively as the adaptation of the tusks (modified teeth) of the elephant, or the enlarged canine teeth of the dog or bear which are used in fighting.

There are many more examples of protective adaptation in mammals. How many can you name?

158. Humane Methods of Care and Protection. — Wild animals are valuable for food and especially for the fur they furnish to man. Those who hunt these animals are usually not in sympathy with any restrictive measures. The early stories of the Hudson's Bay Fur Company tell us of the men who set their traps over a large area, visiting them possibly but once a week. Animals that were caught in these

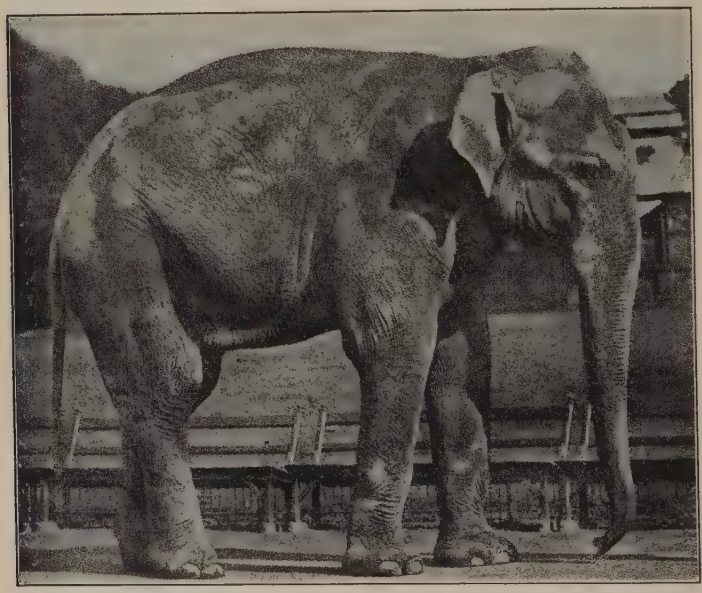


FIGURE 159. — ELEPHANT WITH A HIGHLY ADAPTIVE "TRUNK."

strong steel traps were unable to escape. There was a long period of suffering that should have been avoided. This can be done by requiring trappers to visit their traps often in the cases where traps are the only means of capturing the animal. In some instances the trap can be set under water, and the captured animal is drowned as it struggles in the water. This is a humane method.

From the earliest times it has been customary to make pitfalls where animals are caught in a deep hole and cannot escape. Here there is no suffering, but all such traps require constant attention, and so are frowned upon by trappers.

The S. P. C. A. — The Society for the Prevention of Cruelty to Animals was organized primarily to protect domestic animals: to keep horses from being beaten or overloaded, and to furnish proper care to neglected cats and dogs. But it also provides for the humane killing of strayed or old animals, and takes over the care of pet animals while their owners are away.

Mammal Sanctuaries. — Yellowstone National Park in the state of Wyoming is the main sanctuary for large mammals. Here the bison, moose, elk, mule and white-tailed deer, black and grizzly bears are protected during the entire year. Even such predatory mammals as the timber wolf, coyote, and mountain lion are partially protected in this park. The number that are killed is determined by their relative destructiveness to the other animals in the park. As soon as these predatory animals become too numerous, a few are killed in order to keep them from becoming a serious menace. This is one of the first instances in our country where destructive animals are being preserved in a wild state for educational purposes.

159. Conservation of Useful Mammals. — With the steady growth of population, more and more wild animals have been killed to supply the increased demand for food and clothing. In fact, so great has been the slaughter of some of the most valuable animals that laws have been passed to protect them from total extinction. Some of these laws make it illegal to kill certain kinds of mammals at any time of the year; others protect them only while rearing their young. In the first class in New York State, we have the elk and beaver, and in the second the deer, fox, and raccoon. The laws protecting mammals are not uniform throughout

the United States, and this is one of the reasons why an extra effort should be made by lovers of animals.

These regulations were fairly satisfactory until fashion decreed that furs should be worn summer and winter. In order to supply this whim more than one hundred million hides were sold in the markets of the United States during the years 1919 to 1921, inclusive. This is an enormous increase in the use of the skin of mammals.

Photographed by Byron Harmon.

FIGURE 160. — BISON OR AMERICAN BUFFALO.

In 1860 there were 5,000,000 buffalo in America, in 1903 there were only 1753; but now, owing to the protection which they receive, there are over 10,000 of these animals.

Many of our common mammals were not extensively killed for their fur until 1919. During the three years for which there is a record, over fourteen million muskrats were sold as Hudson seal, nearly twenty-four million insect-eating moles, and over thirteen million hides of the American and Australian opossums were marketed. These are but four of the nineteen kinds of fur bearers recently introduced by the fur trade to replace the original fur bearers whose supply

RED FOXES.

The red fox is one of the few wild animals that have survived as man has come to occupy the land. The secret of his success lies in his skill in outwitting man and dogs. This skill and his remarkable swiftness in running aid him also in capturing his food.

is diminishing. The entire world is being searched to meet this abnormal demand. Many regions have no protective laws, so that the extinction of the fur-bearing animals inhabiting them is imminent, unless we are willing to forego the gratification of our desire to wear furs as ornaments.

The facts just given indicate that in a very few years the great group of fur-bearing animals will be largely found only in the museums and zoölogical parks unless there is a change in the sentiment of the American people. A great amount of pleasure may be derived from watching these animals in their natural surroundings or even from seeing pictures of them. Let us be willing to share this pleasure with the boys and girls of future generations. It will be a moral and spiritual loss to them that is worth much more than the immediate monetary gain to a few fur dealers. The present abnormal destruction is artificial and unnatural.

We should extend to mammals the same kind of protection that we have to birds, wild flowers, and trees. As we have refrained from destroying these beautiful living things, we have come to have a deeper love for Nature. This deeper love for Nature has helped as nothing else can do to make us happy as we go to the parks or woods for rest and recreation.

160. Necessary Destruction of Mammals. — During the year 1922, the United States Bureau of the Biological Survey employed more than 250 expert hunters who killed, trapped, and poisoned approximately 80,000 of the dangerous and predatory mammals. These included 687 timber wolves, 173 mountain lions, 114 bears, 2,827 bobcats and Canada lynxes, and 77,185 coyotes. The extensive grazing areas for horses, cattle, sheep, and goats are in the western mountain and prairie states, where these mammals are numerous.

The president of the State Agricultural College of New Mexico estimates that during recent years 34,350 cattle, 165,000 sheep, and 850 horses were killed by these predatory

mammals in his state alone. These losses meant the sacrifice of 16,000,000 pounds of meat and 1,320,000 pounds of wool, worth all together over $2,716,000. A similar report can be made for each of the fifteen states where numerous herds of domestic mammals are pastured, so that the statement that the United States Biological Survey has effected a saving of more than $75,000,000 in the animals that it has

With permission of Nature Magazine.

FIGURE 161. — WOLF.

protected in the past six years seems reasonable. This great saving has cost the people only $6,080,846.

The Rat, the Worst Mammalian Pest. — Early in our life as a nation the black rat was introduced from Norway. For a time it spread rapidly and soon became a nuisance. Some time after the brown rat came from Europe, escaping from the boats. This animal exhibited from the first great versatility in its habits and food. It was so much more pugnacious

than the black rat that it was but a few years before the earlier immigrant was almost completely exterminated by this later arrival.

These troublesome brutes may possibly do some good as scavengers, but it is so small in comparison to the damage wrought that it is completely overshadowed. The brown rat causes damage to cereals and grains estimated at more than $200,000,000 annually in the United States. In this connection you should read " The Brown Rat in the United States," by David Lantz, Bulletin No. 33, Biological Survey, United States Department of Agriculture.

A new and more successful method for wholesale killing of rats consists in mixing barium carbonate with flour dough which is then made into small round cakes less than an inch in diameter and about one fourth of an inch thick. Barium carbonate is a deadly poison to rats but only slightly poisonous to human beings, livestock, and poultry.

161. Economic Importance of Mammals. — Man finds some animals helpful, some harmful, and some neither. The domesticated mammals, especially the horse, cow, sheep, goat, and pig, are of the greatest use to man in this part of the world. In cold regions, reindeer are the main source of food and clothing, and are also used for beasts of burden. In desert regions, the camel is the most useful, and in hot regions elephants are of great value as beasts of burden. Dogs and cats have long been man's companions. Of the wild mammals, seals and walruses, which live in the water, furnish food, fur, and leather. The whale furnishes whalebone, food, and oil.

Man is learning to make use of the habits of other mammals; for example, we build roosts in the vicinity of swamps and marshes to furnish shelter for bats by day. At night the bats fly about, catching the insects which annoy man and animals. There are harmful mammals, too, such as gophers (gō′ferz), prairie dogs, and rabbits, which injure

man's land and his crops. Rats and mice consume much food and destroy much that they do not eat, besides carrying diseases. Red squirrels damage beds and furniture if they gain access to the house, and out of doors they destroy the eggs and young of birds and the seeds of evergreen trees.

Rats, mice, and guinea pigs have proved of great use in laboratories where the causes and effects of diseases are studied. Their reaction to diphtheria, tuberculosis, cancer, and other diseases is similar to that of man. As a result of these studies the skillful physician is more successful in relieving sufferings.

Various mammals of economic importance such as the rabbit, skunk, and beaver will be discussed more in detail in the following sections. The Report below should be begun now and kept up to date during the year.

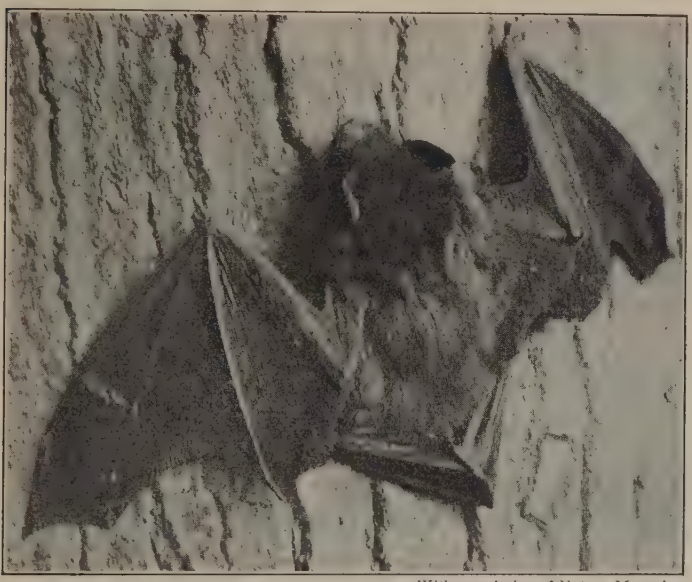
REPORT ON MAMMALS

TO BE FILLED OUT FIRST FROM GENERAL KNOWLEDGE, LATER EXTENDED BY TRIPS TO FIELDS, WOODS, OR PARKS

Kinds	Where Found	Food	Kind of Food	Life in Winter	Life in Summer	Beneficial	Harmful

162. Bats. — This word was applied a long time ago to animals that "fluttered at night," and indicated their chief distinction from all other mammals. Bats all have the bones of the fingers greatly elongated, but there are no more joints or bones in each finger than in your own hand. Over these greatly lengthened fingers is stretched a thin, rubbery wing-membrane which is double in thickness. It is also attached to the side of the body, hind-legs, and tail. In this membrane are found special sense organs that enable the bats

to detect objects as they fly rapidly in the dim evening light. When their eyes are covered with wax so that they cannot see and they are set free, they fly about freely, never touching objects, even avoiding and passing between silken threads. The sense organs that permit the bats to fly so rapidly without injury are numerous hairs that are supplied with nerves.



With permission of Nature Magazine.

FIGURE 162. — BAT WITH EXPANDED WING.

These hairs are stimulated by the rebound of the air from the objects which the bat is approaching.

Their food consists of insects which are captured both with the mouth and the wing-membrane where it is attached to the body. The feeding time varies with the kind of bat, some seeking their food in the early evening, others early in the morning. All of the bats destroy so many insects that we regard them as highly beneficial.

Bats are particular about keeping their bodies clean, licking all parts which they can reach and washing their faces with part of the wing. While they have their own parasites, the widespread idea that bats carry around bedbugs, and are thus undesirable visitors to a house, is not true.

The young are born in early summer and among some kinds are carried around by the mother for the first two or three weeks as she flies at night. After this they are left "hung up" in some retreat while the mother gathers her evening meal. When three months old they are able to fly and forage for themselves.

With permission of Nature Magazine.

FIGURE 163. — BAT SLEEPING.

163. Rabbits. — They are the most widely known of the wild animals and are hunted as game everywhere. There are three kinds of rabbits: the snow-shoe rabbits of the Northern States, the large hares of the western plains, and the cottontails of the eastern United States.

Among the most serious pests in orchard and tree plantations are rabbits. These animals also do considerable damage to garden truck and other farm products.

The cottontail rabbit breeds several times each year during the warmer months, with litters averaging five or six young. The nest is placed in a hollow or depression in the ground and is composed of dead grass lined with fur which the mother pulls from her own body. These animals breed so fast that in spite of their many enemies and the fact that

they are hunted for food they often become so numerous as to constitute a serious menace to food production.

Cottontail rabbits eat leaves, stems, flowers, and seeds of plants and grasses, and the leaves, buds, bark, and fruit of woody plants or trees (Figure 165).

Natural Enemies. — The carnivorous birds and mammals are usually successful in keeping rabbits from becoming a

Photograph by E. N. Sanborn.

FIGURE 164. — RABBIT.

menace. The hawks, owls, and eagles are the chief birds which destroy them, while foxes, minks, weasels, skunks, dogs, and cats are the mammals that prey upon them.

Protection of Trees. — Many devices for protecting apple trees and other fruit trees from rabbits have been recommended. The majority of these consist of paints, smears, or washes, supposed to be distasteful to the rabbit. Some

of these are detrimental to the tree, such as coal tar and pine tar, while carbolic acid affords only temporary protection. Bitter substances are useless against rabbits.

A poisoned wash of starch and glycerin, tried during the winter of 1913–1914 in Idaho by a field agent of the Biological Survey, gave excellent results in protecting young orchards from jack rabbits, and would probably be equally effective where cottontails are concerned. The wash is prepared as follows:

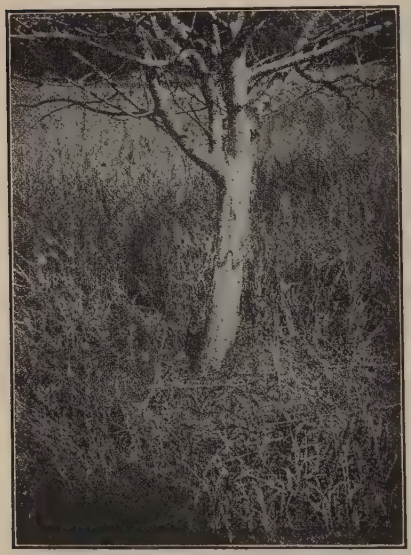


FIGURE 165. — TREE GIRDLED BY RABBITS.

Dissolve 1 ounce of strychnine (sulphate) in 3 quarts of boiling water. Dissolve ½ pound of laundry starch in 1 pint of cold water. Pour the starch into the vessel containing the strychnine and boil the mixture a short time until it is clear, adding 6 ounces of glycerin and stirring thoroughly. When it is cool enough apply with a paint brush to the tree trunks.

The glycerin and starch adhere well and form a thin coating on the bark. Rabbits attacking such trees are quickly killed. In the Idaho experiments none of the trees were damaged badly enough to affect their growth and all the rabbits in the orchards were destroyed. The method is well worth trying; but care should be taken not to endanger domestic animals.

164. Skunks and Weasels. — The skunk is the most common of the wild, flesh-eating animals. It has, as close relatives, the minks and weasels. All of these animals are

capable of discharging a strong and almost suffocating odor when annoyed or angry.

This offensive odor is manufactured in glands located near the tail and is an adaptation that has a decided influence on the habits of the skunk. The skunk is no longer required to be alert to escape its enemies and so has become fat and lazy. Its muscles are soft, and rapid exertion exhausts it sooner than any other member of this group.

The food of the skunk consists of grasshoppers, crickets, snakes, eggs, the young of birds, and field mice. It is only occasionally that a hen is captured, and the general habits of this animal are decidedly beneficial. Skunks hibernate in the winter in the holes of other animals, and it is not unusual for more than one family to occupy the same winter quarters. They usually come out in February and seek what food may be found. At this time there are no insects, so their food consists of such animals as rabbits.

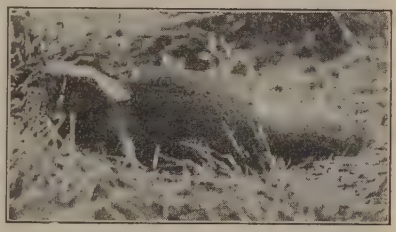


FIGURE 166. — SKUNK.

By May the young are able to begin foraging for their own food, and it is not unusual in the early evening to see the mother and her brood slowly wandering about as they capture insects.

For many years the skin of skunks was sold in the fur market as "Alaskan sable," but at the present time it is more often known as skunk fur. This fur is made up chiefly in muffs and neck pieces, and the demand for it has become so great that regular skunk farms are conducted at a profit, due to the increased price of fur during the past 15 years.

Weasel. — Closely related to the skunks are the weasels, which are very destructive of birds, rabbits, and poultry.

Their thin, muscular bodies enable them to move with great rapidity and their endurance carries them many miles in a single night. It is interesting to contrast the difference in habits between skunks and weasels.

165. The Beaver. — The beaver is one of our most interesting mammals because of its social habits and architectural ability. The demand for its fur and oil has led to

FIGURE 167. — RUNWAYS OF MUSKRAT.

As the water in the pond recedes, the muskrats dig canals that enable them to reach water from their lodges in the bank without going over land. How does this show adaptation in the behavior of these animals? These canals are often mistaken for beaver runways.

its extermination in many parts of the country. In the Adirondacks beavers were trapped and hunted with such vigor that for a few years previous to 1905 none was to be found. In 1905 several pairs were obtained from Yellowstone National Park and liberated near the old beaver haunts in the Adirondacks, and at the same time laws were passed protecting them. Now they are numerous throughout the

Adirondacks wherever natural conditions are favorable. The beaver is frequently selected as an emblem of industry. Some of the interesting facts in connection with the life of the beaver follow.

1. With their strong teeth they are able to cut down trees more than a foot in diameter.

2. They cut up the trees into lengths which they can handle in the water (Figure 168).

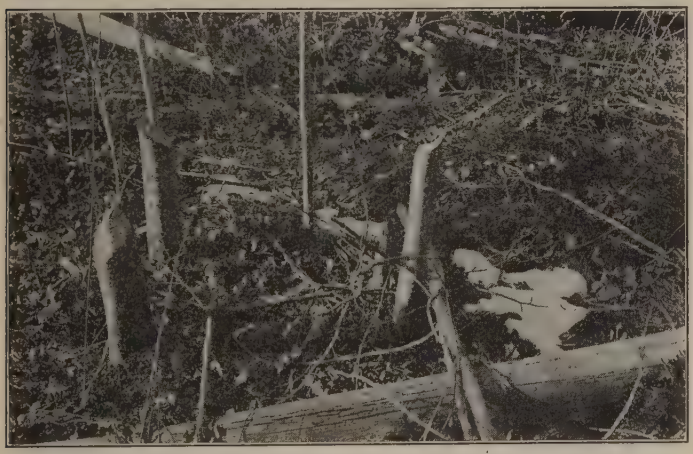


FIGURE 168. — YOUNG POPLAR TREES CUT DOWN BY BEAVER.
Notice the top of the stumps.

3. If the trees are large and there is no water near, they dig canals leading back to the fallen tree.

4. They build dams that are eight or ten feet high and twenty or thirty feet wide. These dams frequently raise the level of lakes so that the shore line is changed (Figure 169).

5. If the stream is large and the pressure on their dam becomes too great, they build a secondary dam below the first one, which provides slack water and thus protects the main dam.

6. Their houses are built of mud and sticks on the margin of the ponds after the dam is finished. They live in these houses and enter them from below the surface of the water. The purpose of the dam is to provide a pond with deep water for their protection and use (Figure 169).

Beavers live in colonies and work industriously in building dams and houses. Some damage is done by their cutting

FIGURE 169. — A BEAVER HOUSE.
What is it used for?

trees and damming up streams. The great popular interest in beavers and their works more than outweighs the little harm they do.

166. The Horse. — The horse is interesting because it has been associated with man since the pre-historic period known as the Stone Age. It has been suggested that man "first hunted horses for food, then drove them, and finally used them for riding and as beasts of burden." The fine animals

which we see to-day have gradually developed through this long time from a small animal about the size of a fox terrier. The earliest remains of the feet of the ancient horse show that it had four toes and the remains of a fifth in the front foot, while the hind foot had three toes and the remains of a fourth. The horse and the deer, which also has many stages preserved in the rocks, afford examples of the manner in which some of our present animals have developed.

FIGURE 170. — A STANDARD BREED OF TROTTING HORSE.

The domesticated horses were developed in the old world. In the warmer regions, where food was plentiful, the largest horses developed, while in the north, where food was less abundant and the conditions were more severe, the Shetland pony appeared. Most breeds of horses were developed in France and England. There are three general types: namely, draft horses, which are the largest and heaviest, with short, strong limbs and thick necks, of which the Percheron, Belgian, and Clydesdale are common types; coach or carriage horses, which are graceful and plump but not so heavy as the draft horses; and roadsters or trotting horses,

which are the lightest and slimmest of the horses. Roadsters have long legs, a thin neck, and are noted for their intelligence. Saddle horses belong in this third class (Figure 170, a fine specimen).

The mule has been known for many centuries. Even in the days of ancient Greece and Rome mules were used in agriculture. They are stronger, more patient, live longer, and are surer footed than horses. Because of their great endurance and adaptability, they are more widely used than horses. Start Mod Sec 7.

167. The Cow. — Cattle are descended from the wild ox of Europe and Asia, and practically all our popular breeds have been developed in Europe, mainly in the British Isles. There are two chief types of cattle: the beef type used for food and the dairy type most valuable for the milk, butter, and cheese that they produce. The beef type is characterized by "blocky" bodies, a form which yields the greatest quantity of meat. The beef cow is not expected to produce much milk. Shorthorns and Herefords, English breeds, also Angus and Galloway, Scotch breeds, are good representatives. The dairy type presents a different appearance from the beef type, having a much less regular body and a very large udder (Figure 171). The Island breeds, Jersey and Guernsey, are among those most famous for the production of butter fat rather than for the quantity of milk. Jerseys are especially valuable as family cows. Guernseys, larger and heavier then Jerseys, yield more milk and more meat. The Ayrshires, a Scotch breed, are known for the superiority of their milk for cheese, for the large proportion of butter fat, and for the fact that they yield more beef than any other dairy breed. Dutch cattle, the Holstein-Friesian breed, are famous for the quantity of milk that they produce. The milk is superior for cheese-making and, on account of the large quantity they produce, these cattle rank foremost in supplying cities with milk. Oxen

of this breed grow to large size and are much prized as work animals.

168. Sheep. — Sheep have been domesticated for ages, being possibly the first mammals domesticated by man. They thrive in nearly all climates and can find food where other mammals can scarcely live. Sheep furnish wool and

FIGURE 171. — COW AND CALF.

This cow gave 653 pounds of milk in seven days and 101 pounds in one day. The 653 pounds of milk yielded a little over thirty-three pounds of butter. The great food value of milk is better appreciated when one remembers that a cow giving 8000 pounds of milk supplies as much food as four 1200 pound steers, or sixteen 200 pound hogs, or thirty-two 135 pound sheep. Several cows have a record of producing 10,000 pounds of milk in one hundred days.

meat. There are three classes, based on the quality of the wool. These are the fine wool breeds like the Merino, which had its origin in Spain, whence they have been carried to all countries where sheep raising is an important industry; the medium wool breeds like the Southdown; and the long wool breeds like the Leicester, both of which are English breeds. The fine wool breed is raised principally for the

wool, the meat value being a secondary consideration. The medium wool breeds are raised principally for the meat, and wool is a secondary consideration; while in the long wool breeds the mutton and the wool are of equal importance. Closely related to the sheep are the goats, which are the main dependence for milk and meat in the Island of Malta, Switzerland, and Asia Minor.

FIGURE 172. — HAMPSHIRE SHEEP.
Excellent for mutton and wool.

169. Pigs. — The pig has been developed from the wild boar of the old world. Meat is obtained more cheaply from the pig than from any other animal, because it adds more weight for a certain amount of food than either sheep or cattle and does it in a shorter time. There are two types in our markets, the lard type and the bacon type, which are produced largely through the methods of feeding. The well-known Berkshires, an English breed, whose color is black, are regarded by many as the aristocrats among

pigs. America is famous for the breeds of pigs developed here, of which the Poland-China, originating in Ohio, the Chester White, first produced in Chester County, Pennsylvania, and the Duroc-Jerseys, of New Jersey, are among the most popular.

170. Other Products for Which Mammals Are Valuable. — Many of the animals we have just been studying supply us with food, fur, and wool. But mammals also furnish us with various other things, such as leather, oil, and buttons.

FIGURE 173. — SOW AND PIGS.

Leather. — The skin of mammals consists of two general layers, the outer (*epidermis*) and inner (*dermis*), a study of which introduces us to some interesting biological problems connected with one of our commonest possessions — shoes. The skin of man is built upon the same plan as the skin of the animals from which the leather used in shoes, harnesses, grips, and gloves is manufactured.

From the skin of the porpoise is secured a leather which can be used for the uppers in the manufacture of boots. From deerskin, gloves and the so-called "chamois" are made.

The leather used in bookbinding comes chiefly from sheep and calfskin. Enameled leather and heavy work-aprons are made from horse hides. Most of the good shoes and boots are made from calfskin, while pocket-books, hat bands, and leather gloves come from sheepskin. Even sealskin when not suitable for furs is used to make the uppers of riding boots and enameled leather, and pigskin is made into portmanteaus and footballs.

This large industry depends upon the structure of the skin, especially the arrangement of the fibers in the dermis. In the skin of a fish or an alligator, the fibers of the dermis run parallel and at right angles in the several layers, while in the hairy animals these same fibers do not follow any order of arrangement, which results in the production of a felt-work of interlacing fibers producing a strong skin which resists tearing or flaking.

Most of the leather that is used in shoes to-day comes from the hides of cattle. Great numbers of these animals are slaughtered each year for food. Their hides must be removed with care to avoid cutting, as all such injuries destroy the fibers of the dermis. These hides are then sent to tanneries where each is made into a certain grade of leather, such as sole leather or the leather for the upper part of the shoe. This difference in thickness and firmness is produced largely by the method employed in tanning. When a vegetable tan is used, such as hemlock bark, oak, or sumac, sole leather results; and when a mineral tan is employed, leather suitable for the upper part of the shoe is secured.

Two common parasites, the white grub and the southern cattle tick, live in the skin and render it unfit for leather, so that it is to the advantage of the cattle breeders to keep their cattle free from these parasites. The United States Department of Agriculture has greatly assisted cattle raisers in exterminating these destructive parasites. The effort to exterminate the parasites, especially the southern cattle

tick, was so successful that in 1918 hides valued at many millions of dollars were added to the general supply in the United States.

Another biological factor in the production of good leather has reference to the care that the cattle receive. If they are well fed and properly housed during the winter and keep free from disease, their hides have a better texture and are finer grained. The coarser grades of leather are made from older cattle and those that have little or no shelter in winter.

Man has never been able to originate or create leather. It must be first grown as the skin of some animal. Man's skill consists in his manipulations of the hide after a living animal has grown it.

Mammals Valuable for Oil. — Oil is the name for fat in liquid form. The edible animal fats are butter, lard, and margarine. Whales supplied in 1922 nearly seventeen million pounds of oil in this country alone. Mutton tallow is used in the manufacture of candles. Tallow, bone fat, horse fat, and the fat squeezed from the skin of animals is used in the dressing of leather. Animal oils serve as a chief source of fats in the manufacture of soap, while a large amount of grease is of animal origin. In 1923 the animal and fish oils, fats, and greases, produced and used in the United States, exceeded one billion pounds and were valued at $118,432,275.

Mammals and Buttons. — In addition to the immense number of buttons manufactured from clams and mussel shells, there is a very considerable industry manufacturing other sorts of buttons. In expensive tailoring real horn buttons are used, sliced from the horns of cattle. However, many of the buttons used on clothing are made from " vegetable ivory," which is a nut and not an animal product. Great numbers of so-called bone buttons are made from the casein in skim-milk. The casein is coagulated, colored, and combined with certain chemicals which give it solidity. These

buttons are made by compression. Not only are buttons made by this process but umbrella handles, hair brush handles, and similar products.

Home Studies on Mammals

Many interesting studies can be made of the life of this group. The different kinds of mammals can be detected by their tracks, the distance between footfalls, claw marks on trees, logs, or ground, tooth marks on wood or bone, their nests, shelters, runways, holes, trails, and dust paths, all tell something about each kind. Where do they live? In the soil, among the rocks, in the water, or the air? What effect do unusual climatic conditions such as storms, floods, and forest fires have? Which ones are active in the winter and which inactive? How is the particular mammal you are studying related to other animals? Who are its enemies and its friends? Does it have the same enemies in youth, middle age, and old age? When does it begin to be active each day? How long is it active and when does its activity cease? Does the animal spend the entire year in one locality or does it migrate? If it migrates, in which direction and how far does it go? Can you find out any of the causes of migration, such as food supply, and changes in climate? For those animals that hibernate the time of entering and emerging from hibernation should be observed. Are they completely inactive during this period? As these animals move about during the active season what is their method of locomotion? Do they run, jump, climb, dig in the ground, swim, or fly? What foods do they eat? Do these foods differ at different seasons? Do they store up any food? Are they dependent on water? What are the various sounds and calls made? Do they have warning calls and alarm calls? The calls of mammals may be described under barking, baying, screaming, howling, squeaking, squealing, singing, roaring, bugling.

These are a few of the natural history studies which you can undertake. They should be made in connection with the Report on Mammals given on page 222.

OUTLINE

- Mammals
  - Defined
  - Kinds of
    - Carnivora
    - Rodents
    - Ungulates
    - Primates
  - Special adaptations
    - Fore-legs
    - Hind-legs
    - Vertebræ
    - For protection
      - Color
      - Hair
      - Teeth
        - Tusks
  - Protection
    - S. P. C. A.
    - Sanctuaries
  - Conservation
    - Laws
    - Regulations
    - Restrictions
  - Destruction
    - Of dangerous mammals
    - Of mammals for food
    - Of rats
  - Economic Importance
    - For food
    - For clothing
  - Typical mammals
    - Bats
    - Rabbits
    - Skunks and Weasels
    - Beavers
    - Horses
    - Cows
    - Sheep
    - Pigs
  - Other Products
    - Leather
    - Oil
    - Buttons

SUMMARY

Mammals are animals that are to some extent covered with hair and that suckle their young. There are nearly always two pairs of appendages that undergo a wide range of adaptations. The wild mammals still furnish us with our furs, some food, leather, and oil. The importance of this group of animals is so great that regulations governing the killing of them during the breeding season have been made, as well as special efforts to destroy the predaceous ones. Our domestic animals which serve us in so many ways have gradually developed into their present form and usefulness. Man had to learn first how to use the fur and skin of wild animals, then how to improve the quality of the fur and skin by careful feeding and breeding of the domesticated animals.

QUESTIONS

How do you tell a mammal from a bird? From a frog? From a fish? What products of mammals do you use daily? Which mammals live near your home? Are they beneficial or harmful? How do you know? Where do they live during the summer? During the winter? What is being done to protect the beneficial mammals in your county?

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CHAPTER XV

THE SIMPLEST ANIMALS — PROTOZOA

A fire-mist and a planet,
A crystal and a cell,
A jellyfish and a saurian
And caves where the cave-men dwell;
Then a sense of law and beauty
And a face turned from the clod —
Some call it Evolution,
And others call it God.

— Carruth

171. Cells. — In our study of the grasshopper and its insect relatives we considered their behavior and life processes. If we had studied the minute structure of any of these insects, the grasshopper, for example, and had used a microscope to aid us, we should have found that every organ was made up of numerous small parts joined together in a definite manner. These small parts are called *cells.*

Any book on biology uses the word *cell* again and again. The name was first used by the Englishman, Robert Hooke, over two hundred years ago, when, with his crude microscope, he examined a piece of bark and found it to be made up of little rooms which looked like the cells of the honeycomb. These spaces he named *cells.* When better microscopes were made, the living parts of the cell were discovered, and it was found that Hooke had seen only the walls of dead cells.

All plants and animals are composed of cells. A cell may exist alone, carrying on all the life processes itself, or it may

exist in connection with a great many other cells, as in all large animals and plants. In every case each cell is produced from another cell.

There are certain animals that are never more than one-celled even when they are full grown. These animals are called *protozoa* (prō-tō-zō′a: Greek, *protos*, first; *zoön*, animal).

The Protozoan Cell. — The protozoan cell is a single mass of living matter called *protoplasm*. In a general way it carries on the same life processes as the grasshopper, or any other animal. When this living cell comes in contact with heat, cold, electricity, chemicals, or other stimuli, it moves, and we say that it is *irritable*. The term *irritability*, used with a scientific meaning, is defined as the *power of being aware of a stimulus*. When this living cell is brought into contact with cold, for example, it makes a definite movement. It is aware of the cold stimulus.

The living cell grows by using food. It takes in oxygen from the water or from the air, according to where it happens to live. It gives off waste substances. It can grow and reproduce other cells of the same kind. The cell is the unit of structure and function in all animals.

Many protozoan cells have no limiting wall between the living substance and the water in which they live. Yet the protoplasm and the water do not mix, though we do not understand why. Other Protozoa living in the ocean are surrounded by extremely thin skeletons of lime. When the animals die their skeletons sink to the bottom and become massed in a sort of rock. The famous chalk cliffs of England were formed in this way.

Habitat. — The habitat of any animal is the place where it lives. The Protozoa are small, usually microscopic, animals common in stagnant pools and in swamp water. They are also common in salt water. In fact, Protozoa are likely to be found in nearly all ponds of water that contain food

for them. Often, in the summer time, our attention is called to the activities of Protozoa when the water from lakes or reservoirs has a fishy taste. This peculiar taste may be due either to animals or plants, or to both. When it is due to animals, it is caused by a disagreeable oil formed by a certain kind of Protozoa.

172. Amœba.[1] — The name *Amœba* (a-mē′ba) is given to several different Protozoa, but all represent the simplest form of animal life known to us. For this reason they are always studied in biology. In order to describe correctly the structure of even so simple an animal as the amœba a few new words are necessary.

FIGURE 174. — PHOTOMICROGRAPH OF AN AMŒBA.

Structure of Amœba. — It is difficult for inexperienced students to see the living amœba through the microscope, because the whole cell has a faint, grayish appearance, and in a strong light is transparent. But if this grayish appearance of protoplasm is once seen, it is always remembered.

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[1] No suggestion can be made which will always enable the teacher to secure amœbæ. They are more frequently found in the slime and mud of stagnant water than anywhere else. Paramecia and other infusoria can usually be secured in abundance by placing a handful of hay or leaves in a jar and covering them with the ordinary water used in the laboratory. This is called a *protozoan culture*, and should be started about four weeks before the material is wanted for class study. The length of time that the culture should stand can be lessened by adding a little beef-extract and by keeping the jar near a radiator. Water sufficient to keep the hay or leaves covered must be added from time to time. When a good culture of Paramecia is once secured, the jar should be kept from year to year, simply adding water to the dried hay left in the jar when Protozoa are desired.

There is no well-defined cell wall; therefore the amœba is an illustration of a living, naked cell. Near the center of the cell is a spherical mass of denser protoplasm called the *nucleus*. In many amœbæ the nucleus is not easily seen except by means of specially stained preparations. The rest of the protoplasm in the cell is called *cytoplasm* (sī′tō-plazm). This does not appear the same in all parts of the amœba.

On the outside, there is a thin, almost transparent layer, called *ectoplasm* (ek′tō-plazm: Greek, *ecto*, outside; *plasma*, form). The larger part of the cytoplasm is filled with numerous small granules and contains several vacuoles (văk′ū-ōl) or tiny cavities. This inner mass of cytoplasm is call *endoplasm* (en′dō-plazm: Greek, *endo*, within; *plasma*, form). The vacuoles in the endoplasm may contain food, water, or waste products. The food and water vacuoles are temporary structures, but the vacuole which collects the liquid waste is always present.

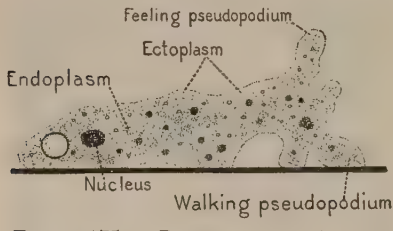

FIGURE 175. — DIAGRAM OF AN AMŒBA.

The living amœba is continually changing shape and pushing out from the surface of its body blunt, finger-like projections of the protoplasm called *pseudopodia* (sū-dō-pō′dĭ-a: Greek, *pseudo*, false; *pod*, root of *pous*, foot), which give an irregular outline to the body (Figure 175). Sometimes the pseudopodia branch out, and therefore the scientific name *Rhizopoda* (rī-zop′ō-dä: Greek, *rhizos*, root; *pod*, root of *pous*, foot) is the technical name for all amœba-like Protozoa.

173. Vital Functions of the Amœba. — The amœba has the same vital functions as the higher animals which we have already studied, but of course they are much simpler in this one-celled organism.

Motion. — When the amœba sends out a pseudopodium in any direction, the rest of the body flows gradually, by a rolling movement, in the same direction. This creeping-rolling motion of the protoplasm enables the amœba to move through the water.

Nutrition. — When the pseudopodium comes in contact with a minute plant upon which the amœba feeds, the protoplasm of the pseudopodium surrounds the plant and takes it into the cell. The microscopic plant thus eaten by the amœba is inclosed, with a small amount of water, in a tiny globe called the *food vacuole*. The food vacuole is to be thought of as a stomach in which digestion can take place, for the plant is digested in it. Digestion is accomplished by means of an enzyme (see page 28). The nutritious parts are absorbed into the protoplasm, the undigested parts are cast from the cell, and the food vacuole disappears.

Food vacuoles are not always round (Figure 177), but take their shape from the form of the plant eaten. If a filament of a simple plant is taken as food, the food vacuole is much elongated.

Respiration. — From the oxygen dissolved in the water, the amœba obtains by osmosis the oxygen necessary to its life, and it gives off carbon dioxide from the cell.

Excretion. — The term *contractile vacuole* is given to a vacuole which is always present in the protoplasm of amœba.

This vacuole can be seen to increase slowly in size, then suddenly contract. As it contracts, the fluid in it is forced to the outside of the body of the amœba. The filling out of this vacuole is due to the collection of excretory wastes from the surrounding protoplasm. It is called a contractile vacuole because it contracts and expands, and an excretory vacuole because it collects waste products.

Reproduction and Encystment. — The chief method of reproduction in the amœba is simple (Figure 176). The

living cell divides into two equal parts, forming two new cells. This process is known as *fission* (fĭsh′ŭn: Latin, *fissio*, cleft).

When the food or water becomes unsuited to supply the needs of the cell, in order to live the amœba often secretes (makes for itself) a thick wall completely surrounding the protoplasm. This process is termed *encystment* (en-sĭst′-ment: Greek, *en*, in; *kystis*, bladder). After the wall has been formed, the amœba is able, for a long period, to resist cold, the drying up of the pond, or the lack of food.

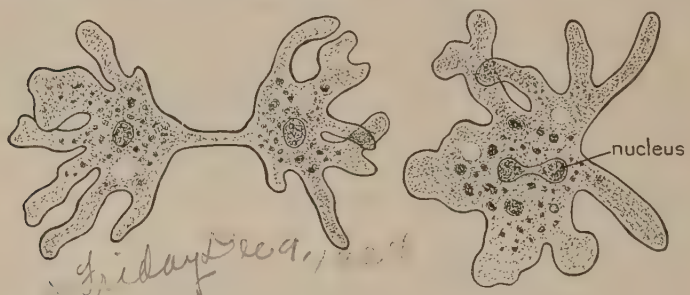

FIGURE 176. — AMŒBA DIVIDING BY FISSION.

174. Paramecium. — One of the most common forms of Protozoa is the slipper-shaped *Paramecium* (para-mē′-sĭ-um), which is more active than the amœba. It is abundant in stagnant water and in the hay infusions prepared in the laboratory. (See footnote, p. 243.)

LABORATORY STUDY

There are certain kinds of Protozoa that are usually found in protozoan cultures. The most abundant form is the paramecium. With a microscope make repeated examinations of drops of water from the protozoan culture, until you are able to find the paramecium. Notice its shape, rate of movement, behavior on meeting obstacles, and the like. Report on what you can make out. Compare the paramecium with any other protozoön you can find, as to shape, rate of movement, size, color, etc. If available, examine slides which show the nucleus of a protozoön. Make sketches that illustrate the above features.

Structure of Paramecium. — The paramecium, like the amœba, is a single cell, but it has both a large nucleus and a small one. It has an endoplasm, an ectoplasm, and a *cuticle* (kū′ti-kl), or cell wall. Through the cuticle there extend great numbers of *cilia* (sĭl′i-a), or threads of living protoplasm. The ectoplasm contains many thread-like darts known as *trichocysts* (trĭk′o-sists). These can be discharged. Within the cell are found food and water vacuoles as in the amœba; but there are two contractile vacuoles, one at either end, and the food and water vacuoles are more numerous than in amœba.

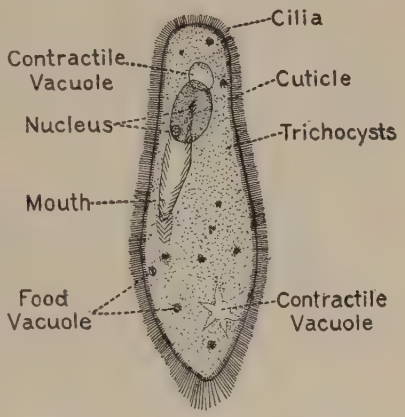

FIGURE 177. — DIAGRAM OF PARAMECIUM.

175. Functions and Life Processes of Paramecium. — The life processes of the paramecium are not quite so simple as those of the amœba, but are far less complicated than those of most of the animals we have studied.

FIGURE 178. — PARAMECIA STAINED TO SHOW THE NUCLEUS (Photomicrograph).

Locomotion and Defense. — The animal moves by the action of the cilia, the direction depending upon the angle at which the cilia are held. It can be observed that the animals move backward and forward, and that they also

rotate on the long axis. Paramecia defend themselves by discharging their trichocysts. This discharge occurs either as a result of certain strong artificial stimuli, such as electric currents or chemicals, or naturally because of collision with certain other Protozoa. If attacked by some animal which feeds upon them, they discharge the trichocysts in the region of the attack (Figure 179).

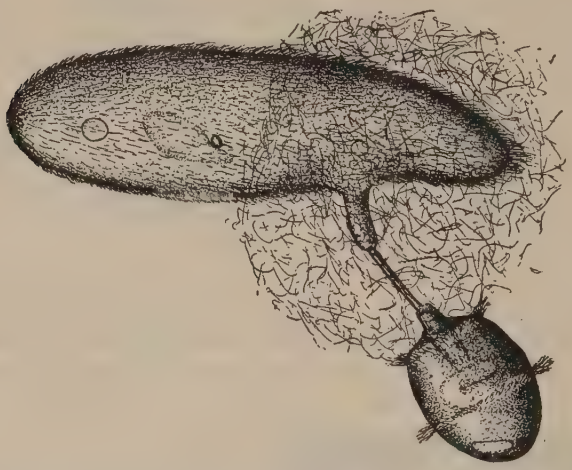

FIGURE 179. — PARAMECIUM

Being attacked by another protozoön that feeds upon it. The trichocysts are discharged, and they force the foe away.

Nutrition. — The paramecium, like all other living things, requires food, which consists mostly of bacteria. These are collected by means of the cilia located on each side of the fold or depression called the gullet. At the inner end of the gullet is the mouth (Figure 177). The food thus collected passes into protoplasm in the form of food vacuoles. Digestion is accomplished by the aid of enzymes which put into solution the available parts of the food it eats, and the indigestible parts are cast off from the body.

Respiration. — As in amœbæ, the oxygen which is necessary to respiration is obtained directly from the water and passes into the protoplasm at all points.

Excretion. — Excretory wastes are first collected in each of the two contractile vacuoles and then cast from the body. Gases escape from the entire surface.

Irritability. — Both the amœba and paramecium respond to jars, food, and their enemies in a definite manner. In each of these simple cells there is no structure which can be compared to the nerve cells or brain of higher animals. The ability to respond to stimuli in Protozoa seems to be a condition that is present in the whole protoplasm of the cell.

FIGURE 180. — PARAMECIUM BEFORE AND AFTER DIVIDING.

Reproduction. — Paramecia reproduce by fission, *i.e.* an animal divides, producing two; these divide and produce two more. The process of fission goes on indefinitely (Figure 180). Unlike the amœba these forms cannot encyst when conditions of life become unfavorable.

FIGURE 181. — MALARIAL PROTOZOÖN IN BLOOD CORPUSCLE.

176. Other Protozoa. — If we examine stagnant water, we shall find a large number of other kinds of Protozoa. The more common forms are much like the paramecium and have many cilia on the

body. Several of these large, ciliated Protozoa feed on the smaller Protozoa. Some of the common forms are shown in Figures 182, 183, and 184.

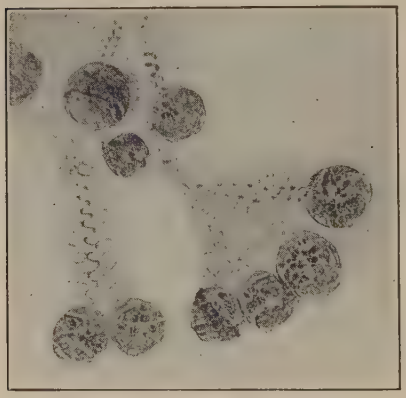

FIGURE 182. — VORTICELLA.

This protozoön is supported on a stalk which can contract and expand. Of what use is this?

All these various Protozoa can be grouped into classes, each with certain distinct characteristics. For instance, all Protozoa that have pseudopodia are called *Rhizopoda*. In this group, the cells may be naked or may possess a hard mineral covering; a second group of Protozoa are provided with one or more long, wavering threads called *flagella* (flā-jel'la: Latin, *flagellum*, whip), and have the name *Flagellata;* the flagella are longer than cilia and show more complicated movements. A third class, known as *Infusoria* (in-fū-sō'ri-a), includes most of the common Protozoa found in protozoan cultures. Many of this class are provided with cilia.

Economic Importance of Protozoa. — By far the greater number of Protozoa are harmless, and many are helpful in that they serve as food for fishes. Others, however,

FIGURE 183. — SOME FLAGELLATE PROTOZOA.

may become parasitic in our bodies and so cause such diseases as malaria, yellow fever, and sleeping sickness. These disease-producing Protozoa are of great economic importance to man, because they prevent him from carrying on his work.

Paramecia consume considerable quantities of bacteria, but we do not know whether most of these are helpful or harmful. For this reason the economic value of paramecia is uncertain.

FIGURE 184. — ONE OF THE FORAMINIFERA.

177. Review of the Vital Functions of Animals. — Now that we have studied various forms of animal life and have seen that all have practically the same functions and life processes, it is interesting to review and compare these. In making this comparison we should observe especially the various adaptations which they use to perform these functions. Prepare a table on the plan suggested by the following outline, giving the adaptation of each animal so far studied.

LIFE PROCESSES

ANIMALS	RESPIRATION	LOCOMOTION	FOOD-TAKING	REPRODUCTION, ETC.
Grasshopper				
Bee				
Caterpillar				
Fish				
Frog				
Bird				
etc.				

LABORATORY STUDY OF THE EFFECT OF ALCOHOL AND TOBACCO ON PARAMECIA

An experiment demonstrating the effect of narcotics on paramecium may be performed with very simple apparatus, — two pipettes or medicine droppers, a piece of black paper or cloth, and a dissecting lens, hand lens, or powerful reading glass. The necessary solutions consist of a good paramecium culture, a six per cent solution of alcohol, and a third solution prepared by bubbling tobacco smoke through about one ounce of water until a light amber color is produced. This solution keeps well and may be prepared several days in advance. Fill one of the medicine droppers about half full of water and make an ink mark on the glass at the water level, then force the water out of the dropper and determine the number of drops. Again fill the dropper to the level of the ink mark, force out one half the number of drops already determined and make a second ink mark at the level of the water remaining in the tube.

1. To show the effects of alcohol upon paramecium fill the graduated medicine dropper to the level of the lower ink mark from the six per cent alcohol solution, and then, before relieving the pressure on the rubber bulb, draw into the pipette enough of the paramecium culture to raise the water level to the second ink mark. Place the dropper on the black paper and examine with the magnifier. The organisms will appear as small, white, rapidly moving objects. If the second pipette is filled with paramecium culture and placed beside the graduated pipette the observer can compare the paramecium, being affected by alcohol, with normal paramecium. Note that the organisms in the alcoholic solution are distinctly more active than those in water. This condition soon becomes reversed and within ten minutes those subjected to alcohol die. The actual strength of the alcohol in the pipette is about three per cent, because of the dilution with water containing paramecium. This percentage of alcohol is much lower than that found in many patent medicines and flavorings.

2. To show the effect of tobacco smoke on paramecium fill the graduated medicine dropper to the first ink mark, from the solution previously prepared by treating water with tobacco smoke, and then draw into the tube sufficient water from the paramecium culture to raise the level to the second ink mark. Examine as in part one. At first the paramecium will show about the same amount of activity as those in the normal media, but their activity will gradually decrease until at the end of ten minutes all movement will cease and the organisms will be seen lying on the lower side of the tube.

LABORATORY STUDY OF PROTOZOA

Take a drop of water from an infusion rich in Protozoa; place on a slide and examine with a 16 mm. or $\frac{2}{3}$ objective. Answer the questions suggested by the report.

Number of Kinds Observed	How Many Kinds —		How Many Kinds Have —			
	are free swimming?	are attached by threads?	even motion?	zigzag motion?	constant form?	varying forms?

OUTLINE

- Cells
  - Protozoan Cell
    - Protoplasm
  - Habitat
- Amoeba
  - Structure
    - Nucleus
    - Cytoplasm
    - Ectoplasm
    - Endoplasm
      - Vacuoles
    - Pseudopodia
  - Vital functions
    - Motion
    - Nutrition
    - Respiration
    - Excretion
    - Reproduction
- Paramecium
  - Structure
    - Endoplasm
    - Ectoplasm
      - Trichocysts
    - Cuticle
  - Functions
    - Locomotion and defense
    - Nutrition
    - Respiration
    - Excretion
    - Irritability
    - Reproduction
- Other Protozoa
  - Rhizopoda
  - Flagellata
  - Infusoria
- Economic importance of Protozoa
- Review of vital functions of animals

SUMMARY

Protozoa are the simplest group of animals. They are found mostly in water, yet some are parasitic in higher animals. They are small and usually consist of only one cell. They reproduce mostly by fission. Some produce diseases in man and beast, such as malaria and the sleeping sickness of Africa. But the great majority of Protozoa are not harmful.

QUESTIONS

Compare the body of a protozoön with the body of a grasshopper. In what are they alike? In what different?

Compare the amœba and paramecium.

Explain how the Protozoa eat, digest food, produce more Protozoa, and protect themselves.

How do these vital processes compare with the similar vital processes in the grasshopper?

In what ways are Protozoa injurious to man? Are they parasitic?

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Jordan and Kellogg, Animal Life, Chapters II, III.
Kellogg, Animals and Man, Chapter V.
Osborne, Economic Zoölogy, Chapter II.

PART III

THE APPLICATION OF BIOLOGIC PRINCIPLES TO THE HUMAN BODY

CHAPTER XVI

RESEMBLANCES BETWEEN MAN AND OTHER ANIMALS

Man is a tool-making animal.
— FRANKLIN

178. Man as an Animal. — In studying animals and plants, we have emphasized the life processes. We have found that each living thing can be analyzed according to its food habits and the place where it lives; its structures used in securing life-giving oxygen and removing wastes; its organs for responding to light, heat, cold, sound, etc.; and finally its methods of producing more living things like itself. We also found in plants an additional life process, the ability to manufacture their own food from the uncombined and non-nutritious elements in the air and soil. As we approach the study of man, we naturally ask how all these facts that we have learned about animals and plants help us to understand how man lives.

Perhaps the best way to learn about man is to study his life processes just as we did the grasshopper's and the frog's. In such a study we may omit the comparison with plants except incidentally, because man is an animal in all the points in which our comparison is to be made, and the similarities between animals and plants have already been em-

phasized on page 211. This does not imply that man is nothing more than an animal, but simply that in many features of his life he lives as animals live.

179. Antiquity of Man. — Many men who have made a special study of the fossil remains of man in the rocks believe that man began living in Europe about 25,000 years ago. This is their estimate of the length of time that has passed

FIGURE 185. — REINDEER.

This figure was carved on stone in a cave in Southern France, where the reindeer has been extinct for many thousand years.

since the rocks were formed in which are found jaw bones or the bones of the legs and arms. In all such cases so far there has been no difficulty in recognizing these fossil bones as belonging to man, although the races of people who lived fifteen or twenty thousand years ago no longer exist.

Man's earliest homes must have been the shelter of trees and an occasional cave, and it is in certain caves in Spain and France that many early records of man are to be found.

There is no record of when man first began to use fire or to build definite shelters. In fact, both these necessities in our cold climate were not as important to early man, because he appears to have wandered about in tropical and sub-tropical regions. This was even true of the climate of Spain and France in the period when he lived in the caves which have become famous for their many records of the early life of man. With the coming of the glacial period, the climate of all northern Europe and northern America became much colder, and the men who lived in regions that were influenced by the southward movement of the ice sheets had to adopt some means of keeping warm or perish.

180. Man's Adaptability. — As soon as men became so numerous that they needed to go farther afield for the necessary food, protective measures were gradually introduced. Moreover, the same forces that compelled early man to migrate have continued to impel man to move out into unknown parts to see if he can find a place to live more easily. We shall see how this has come to have a vital influence upon our own lives as we examine more fully into man's life processes.

We have lived so long in heated houses that we feel that it would be impossible to get along without a furnace fire; but we have all read how whole sections of France during the war had no heat and that our American soldiers were able to adjust themselves to what seemed to most of us an almost impossible change. This teaches us two important lessons: first, it shows something of how early man lived; and secondly, the wide range of adaptation in the body of modern, civilized man. This second lesson is very important because it encourages us to undertake physical difficulties which we had thought impossible; because we now realize that we can overcome them after having the heroic examples of the men, women, and children of Belgium and France.

It is also easier now than ever before to realize how man can live in all parts of the earth. When we described where frogs, fish, and grasshoppers were to be found, certain limits had to be made. Not so with man. He possesses something that no animal has — the power to rise above the limitations of his surroundings. This he does by building a house of ice in the northlands and spreading a tent of cloth in Arabia. His constructive ability has led man to invent various devices for his protection such as stone, brick, wood, or concrete houses, something that no animals are able to do in a manner that justifies their being compared with man in this respect. It is true that birds build nests, but they are always built in the same fashion; and it is true that beavers build dams, but they are always made of wood. The reason that man is able to do more different things than animals is because he has a better mind, a mind that can adapt itself to many different kinds of work, such as that done by carpenters, engineers, lawyers, teachers, etc.

Tell what you can about the range of adaptation in animals that have not been domesticated by man. These simple and well-known comparisons give you some indication of the sense in which man and animals are similar, and it is in this sense that we wish you to work out the comparison of the life processes of man with those of animals.

Scientists give four reasons in explaining why certain animals and plants are not adapted to living in all parts of the world: (1) lack of suitable food; (2) failure in adapting their lives to the peculiarities of climate; (3) too many enemies; (4) inability to raise their young. All these man has been able to overcome.

STUDENT REPORT

The following table points out some of the common adaptations in animals. How are they related to the animal's success in life? Name some other habits which help to protect animals.

	Active in Summer	Active in Winter	Home				Protection				
			Earth	Water	Air	Nest	Night Feeding	Day Feeding	Color	External Skeleton	Method of Escape
Earthworm											
Fly											
House Sparrow											
Dog											
Man											
etc.											

181. Youth, Maturity, Old Age. — The life of man is divided into three general periods, which are youth, the period of maturity, and the period of old age. These same terms are given when describing the life of animals and plants.

Youth is the period when living protoplasm always grows, if furnished with proper food. This is the time when boys and girls grow taller and heavier each year; when the tree grows new leaves and the limbs become longer; and when the small puppy is turning into a full-grown dog. During this period of change the boys and girls, the tree, and the puppy are all nourished by food, and this makes it possible for them to grow.

Maturity is the period when man ceases to grow taller, although he continues to eat food as he did during the period of youth. The living protoplasm in his body does not increase in amount. The same can be said of the tree, for it does not grow taller; and the puppy of last year has become a full-grown dog. During this period of maturity, each living organism is able to repair its body as fast as the body wears out. The period of maturity varies with differ-

ent things; in some butterflies lasting but twenty-four hours, in man continuing for about twenty-five years.

Old age in man begins when the body wastes faster than it is repaired, and in the tree when growth is over and decay begins. During this period of old age all living things use food as they did in youth and maturity, but it cannot build up the body as fast as it is worn out and death is the final result. Old age occurs in different ages in different individuals; and the same is true of animals and plants.

SUMMARY

Man has the same life processes as the animals. He is able to live in all climates and localities in the earth. No plant or animal can do this. Civilized man has learned to control his surroundings. Animals and plants *are controlled* by their surroundings. Man like all other living things passes through periods of growth, known as youth, maturity, and old age.

QUESTIONS

What have you learned about plants and animals that will help you to understand how man lives? Where are the earliest records of man found? Why do men migrate? Why can man control his environment? How do you understand the terms youth, maturity, and old age?

CHAPTER XVII

GENERAL STRUCTURE OF THE HUMAN BODY

Know then thyself, presume not God to scan,
The proper study of mankind is man.

—Pope

182. Superiority of Man. — In the last chapter, we saw how man came to live in all parts of the world in well-made houses to protect himself from the cold and rain. In this respect he is superior though similar to all other animals. As we studied his use of food, there was seen also to be a fundamental similarity between man and animals. Now as we take up the next life process of movement the same relationship will appear.

We usually think of man as walking or running, and it is only when we witness an acrobatic performance that the wide range of movements possible to man is realized. That man can do so many more things with this body than any other animal is due to the greater development of his nervous system. The structures by means of which he moves and which are described in this chapter are the skeleton and the muscles.

183. Regions. — The body of man like that of all the other higher animals is divided into the head, trunk, and limbs. These are the *regions* of the body. The limbs are built on the same general plan as the fore- and hind-legs in mammals. The trunk is divided into the chest, or *thorax*, and the *abdomen*.

In the body of man there are three important cavities; namely, the cranial or brain case, the thoracic, and the ab-

dominal. In the cranial cavity is found the brain, the base of which passes through a large opening (Figure 187) to continue as the spinal cord of the nervous system (Figure 246). The thoracic cavity contains a pair of lungs and the heart. This cavity is separated from the abdominal by the muscular diaphragm (Figure 186). In the abdominal cavity are found the stomach, intestine, liver, kidneys, and reproductive organs (Figure 186).

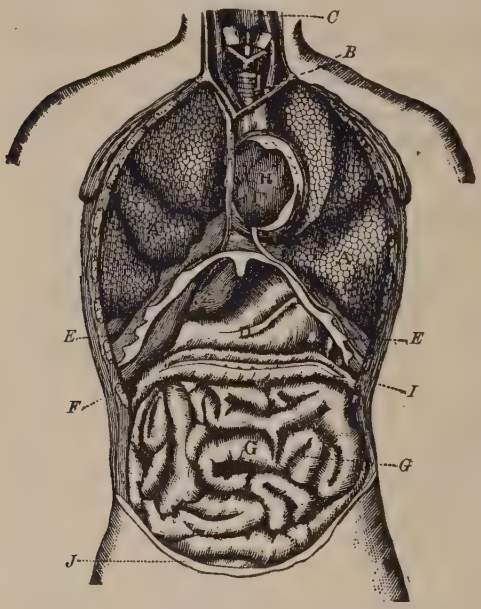


FIGURE 186. — THORACIC AND ABDOMINAL CAVITIES.

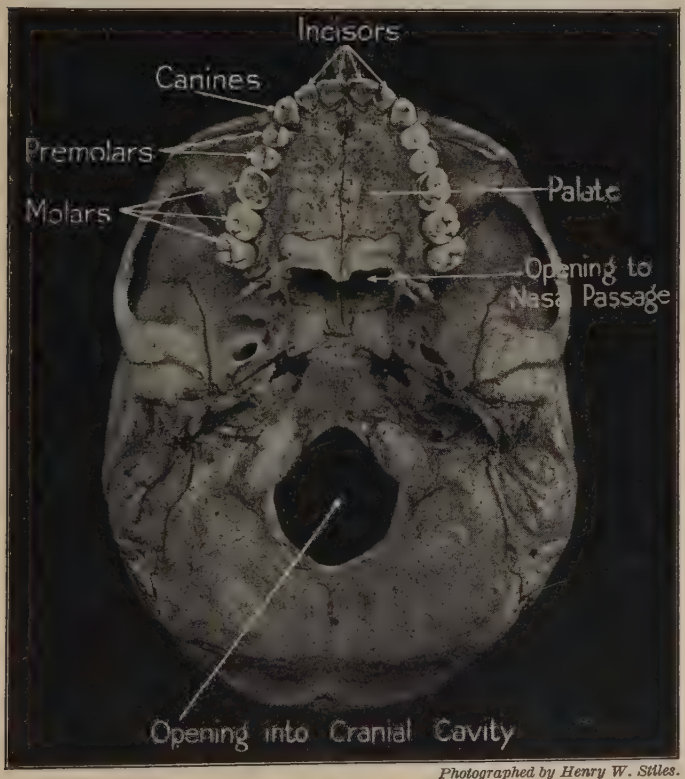
A, lungs; *B*, trachea; *C*, esophagus; *D*, stomach; *E*, diaphragm; *F*, liver; *G*, intestine; *H*, heart; *I*, spleen; *J*, bladder.

184. Skeleton. — The skeleton of the crayfish is almost entirely on the outside of the body. In the fish and the frog you were introduced to the internal skeleton; the position of the skeleton in the fish, frog, bird, mammal, and man is the same, and is one of the important ways in which we recognize that an animal belongs to the vertebrates. The skeleton of man, because of his erect position, seems at first sight to be quite different from that of the dog or horse, but as we examine the parts more fully, we shall see that they are really quite similar.

There are more than two hundred separate bones in the adult human skeleton. For convenience we will describe

the skeleton under the following divisions: skull, spinal column, ribs, sternum, long bones of arm and leg, pectoral and pelvic girdles.

Skull. — The bones of the skull are usually described under (1) the cranium proper, which is the bony case that



Photographed by Henry W. Stiles.

FIGURE 187. — VIEW OF SKULL FROM BELOW.

surrounds the brain, and (2) the bones that form the skeleton of the face. In the adult skull the bones have become fused and their outline is recognized often with difficulty. In

early youth the joints between the bones are movable and allow for growth. The general shape of the skull is such

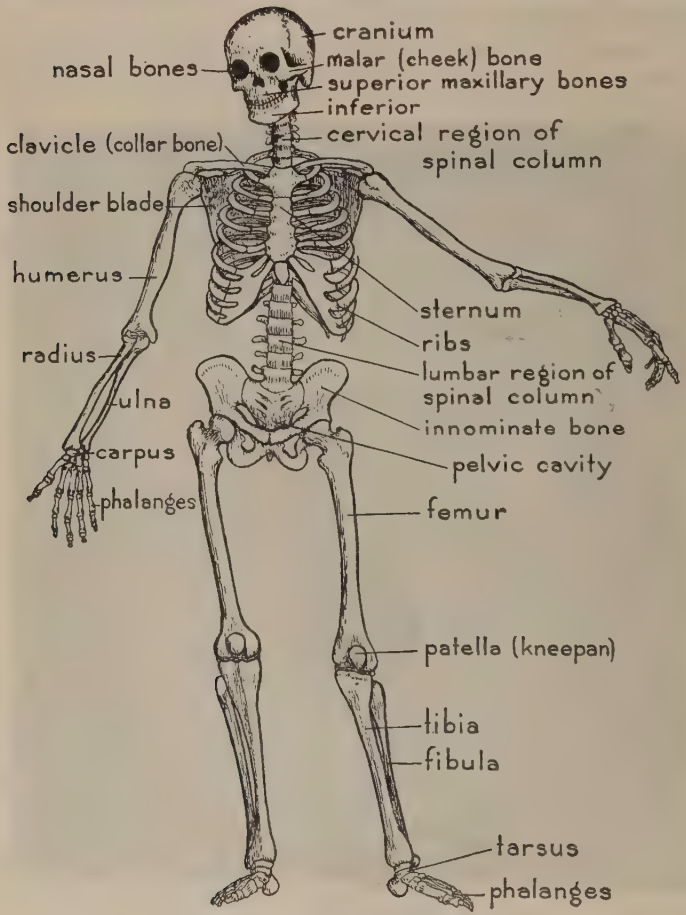
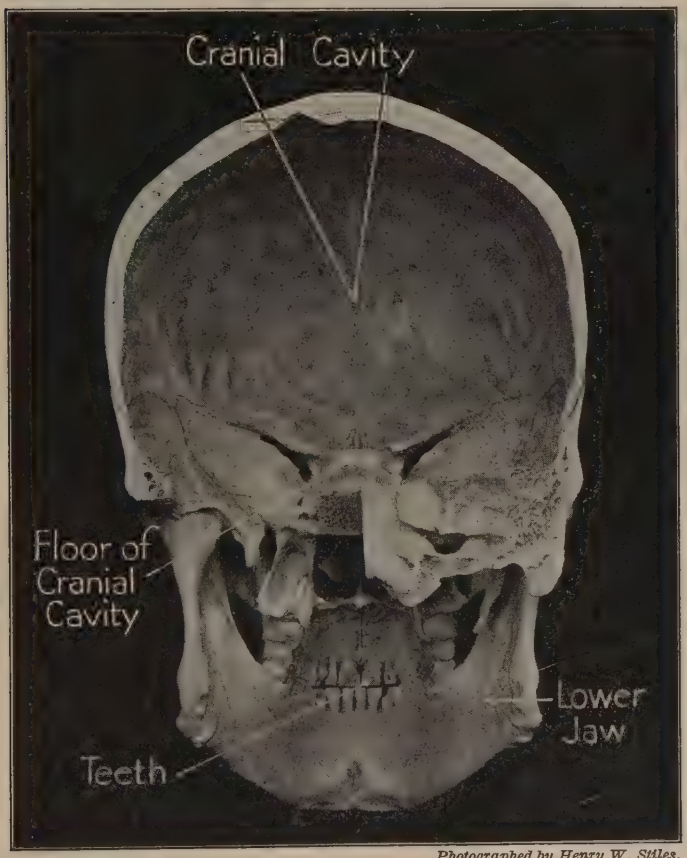


FIGURE 188. — SKELETON OF MAN.

that it gives very complete protection for the brain, and its arched surface is of great strength. The deep sockets in the front, protect the eye. The important parts of the ear

with all of its delicate portions are inclosed by bones of the cranium and are thus completely out of danger.



Photographed by Henry W. Stiles.

FIGURE 189. — FRONT VIEW OF SKULL.

The bones of the face are mostly paired. The prominent cheek bones are just below the eye sockets and are separated by the bones of the nose. The upper and lower jaws con-

taining teeth constitute the remaining important bones of the skull.

Spinal Column. — The spinal column consists of thirty-three segments, or *vertebræ* (Latin *vertere*, to turn, because these bones turn more or less on each other). You can easily recognize the bones in the spinal column by running the fingers along the neck and down the middle of the back. The spinal cord is protected by the several vertebræ so that the entire nervous system is almost fully surrounded by bone. The different vertebræ permit a limited amount of movement which enables us to turn and bend the trunk in various directions. At the same time these vertebræ piled one on top of the other constitute a strong support for the weight of the body and the head.

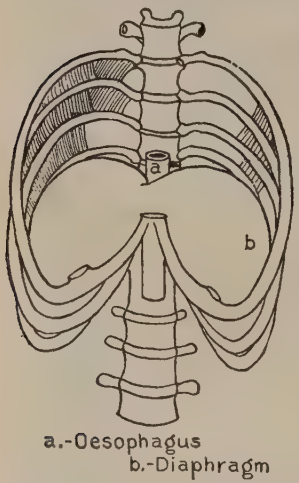


FIGURE 190. — DIAGRAM TO SHOW THE RELATION OF THE DIAPHRAGM TO THE RIBS.

Between the ribs are shown some of the intercostal muscles that assist in respiration.

Ribs. — There are twelve pairs of ribs. These are slender curved bones with one end attached to the vertebræ of the back and the other end attached, directly or indirectly, to the sternum (Figure 190). The attachment of the ribs to the sternum is in part by flexible cartilage. This permits the freedom of movement necessary in breathing.

Sternum. — The breast bone or sternum in man consists of a single piece and serves for the attachment of the ribs. In childhood this bone consists of several distinct parts.

Long Bones of Arm and Leg. — The arm and the leg of man are built upon the same plan. In the arm there is the long bone, the *humerus*, which extends from the shoulder to the

elbow; the two bones in the fore-arm, the row of small bones in the wrist which move freely upon each other, and the bones of the fingers. Similarly, there is the long upper part of the leg, the thigh bone or *femur*, that extends from the hip to the knee and corresponds to the humerus of the arm; then, there are the two bones that go from the knee to the

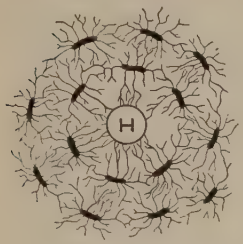


FIGURE 191. — DIAGRAM TO SHOW THE STRUCTURE OF BONE.

The large circle, H, is a branch of the Haversian canal where the blood vessels are found. The spaces between the lines and oval black masses are bone.

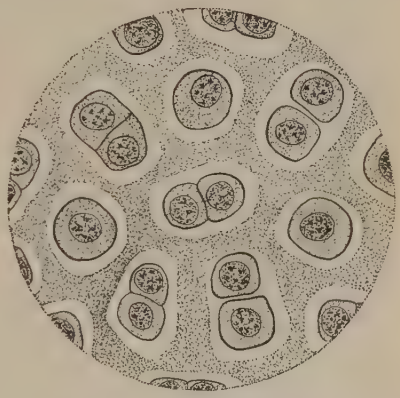


FIGURE 192. — CARTILAGE.

Note that the living cells are separated by spaces represented by small dots.

ankle, the several bones in the ankle, and the bones of the toes. The knee cap is an extra bone.

Pectoral Girdle. — The pectoral girdle consists of the two bones which join the humerus at the shoulder. One of these, the collar bone, *clavicle*, connects the upper end of the sternum with the shoulder. The second bone is the shoulder blade or *scapula*. This is a large flat bone on the back of the shoulder and serves as a most important surface for the attachment of the powerful muscles that are partly responsible for the movements of the arm.

Pelvic Girdle. — This is frequently known as the hip girdle, and really consists of six bones which in the adult are firmly

united into a complete girdle. The pelvic girdle joins a number of the vertebræ which have become fused into the *sacrum*. The union of the bones in the pelvic girdle furnishes a firm base of support for the body and at the same time permits a large range of movement in the legs.

FIGURE 193. — X-RAY OF HAND OF CHILD.

The bones in the wrist are forming. Between the joints of the fingers are seen small bones that later unite with the bones of the hand. Compare with Figure 194.

185. Functions and Adaptations of the Skeleton. — From the preceding paragraphs we see that the chief functions of the human skeleton are to support the various parts of the body and to protect the delicate organs. To this it is especially well adapted, almost the only important portion of the body which is not so protected being the abdominal cavity.

186. Bone and Cartilage. — Unlike the rest of the body the skeleton proper is hard. It consists of bone and a comparatively soft substance known as *cartilage*, or gristle. There are cells in the bones just as there are cells in the liver, the muscles, and in the nervous system. Like the other parts of the body, the bones grow because the individual cells are supplied with food from the blood.

Cartilage occurs near the ends of the bones, in the ear, and in the nose. It is especially prominent in the wrists and

ankles of children. Therefore children should not be lifted by their hands or allowed to stand until a certain amount of bone has taken the place of this soft cartilage. This is readily appreciated when one examines an X-ray of the wrist of a child, which is almost entirely composed of soft cartilage,

FIGURE 194. — X-RAY OF HAND OF ADULT.

What changes have taken place since childhood?

FIGURE 195. — X-RAY OF DISLOCATED FINGER.

while the adult wrist has well-formed bones. The transition from soft cartilage to hard bone is due to the formation of mineral matter that takes the place of the cartilage. Adult bones have more mineral matter than the bones of children.

187. Joints. — The numerous bones in the skeleton allow the body to move although giving a certain amount of rigidity

and permanence of shape. Wherever two bones meet and allow movement, the term *joint* or, more technically, *articulation*, is applicable. The joints are divided into three classes: immovable joints, movable joints, and mixed joints. *Immovable joints* (sutures) are found in the skull of the adult. The bones of the skull do not become firmly united until the head has reached full size, after which no movement takes place between these bones.

FIGURE 196. — X-RAY OF BROKEN FEMUR.

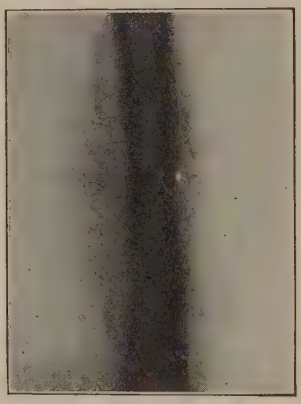


FIGURE 196 *a*. — X-RAY OF THE SAME BONE AFTER HEALING.

Notice the large "callus" of newly formed bone which makes this bone stronger than before it was broken.

Movable joints are the ball-and-socket joint in the shoulder and the hip and hinge joint in the elbow, wrist, knee, and ankle.

The mixed joints are those of the spinal column, which allow only a limited movement.

The movable joints are bound closely together by strong bands of connective tissue. These bands are called ligaments. The tearing or stretching of these ligaments is called a sprain.

188. Broken Bones. — When the bones of a limb are broken, the physician sets them, *i.e.* places the broken ends

together, and puts splints on the limb to keep the parts from slipping until the new bone has formed (grown) and hardened. In Figure 196 is shown an X-ray photograph of a recently broken femur. In Figure 197 the same bone is shown. A large "callus" of new bone has formed around the broken ends, which gradually hardens, making this part of the bone stronger than ever.

189. Structure of Bone. — One of the long bones from the arm or leg illustrates best the several parts. There is the long shaft with knobs on each end. These enlargements are the heads of the bone. The outer surface is covered with a tough membrane. If such a bone is sawed lengthwise, the following additional parts can be recognized: the long central cavity of the shaft filled with marrow; the hard bone of the shaft; the spongy bone toward each end; and the thin layer of cartilage covering each head.

FIGURE 197. — LONGITUDINAL SECTION OF FEMUR, SHOWING THE COMPACT AND SPONGY TISSUE OF BONE.

LABORATORY STUDY

Study the skeleton, and examine long, flat, and irregular bones. How is the bone modified to do its work?

By means of a manikin, models, or organs of an animal, observe the general structure of the principal organs of the body.

If one compares such a bone with a rib or shoulder blade, the central cavity is greatly reduced, having the marrow mostly confined to the spongy portion of the bone.

The frame of a bicycle is a practical application of the principle that a hollow cylinder, like a hollow bone, gives the greatest amount of strength with the least weight.

STUDENT REPORT

Make a report on the skeletal structures of animals as follows:

	Absent	Jointed	Not Jointed	Horny	Bony	Internal	External
Paramecium							
Crayfish							
Clam							
Frog							
Man, etc.							

190. Muscles. — The muscles are the lean parts of the flesh of animals. They are covered by the skin and are usually dark in color. Birds are an exception, for their breast meat is generally white. Muscles are of two kinds: *voluntary* (governed by the will), such as those which we use in walking, or in moving the arms, Figure 198; *involuntary*, such as those which move the food along the digestive tract or assist in breathing.

Figure 198. — Voluntary Muscle Cells.

Showing how the cells are bound together with connective tissue. At the end of the muscle the cells of the connective tissue form the tendon.

The voluntary muscles consist of many long muscle cells (fibers) bound together by connective tissue into a distinct bundle. Usually the muscle bundle is attached at each end to the bones through the tendon of connective tissue. A single muscle moves the arm in one direction only, and in order to lift the arm from the desk to the head, for instance, several muscles must act together.

Figure 199. — Involuntary Muscle Cells.

The cells of the involuntary muscles are unlike the cells of the voluntary muscles. Involuntary muscle cells occur in layers in the walls of the digestive tube, blood vessels,

the bladder, and the like, and they are not under the control of the will.

The muscular tissue of the heart has characteristics of both the voluntary and involuntary muscles, so that it may almost be said to belong to a special class.

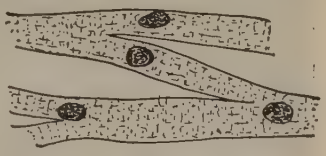
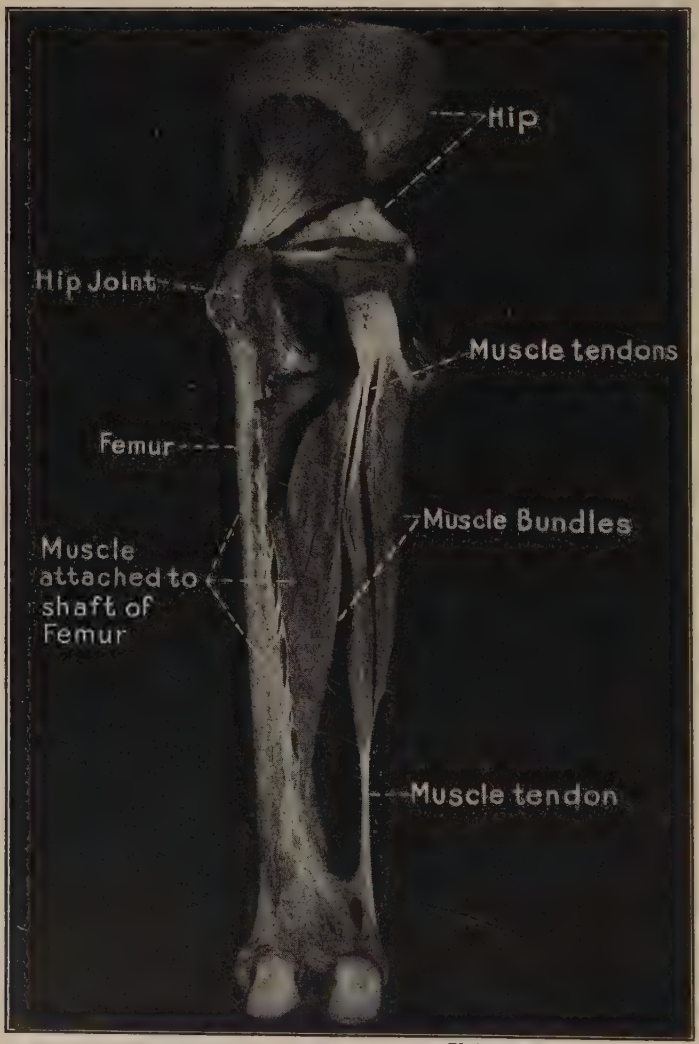


FIGURE 200. — HEART MUSCLE CELLS.

191. Importance of the Muscles. — When we remember that 40 per cent of the weight of the human body is in the muscles alone and that one fourth of the blood is found in these same muscles, their importance is appreciated. But this great mass of tissue so richly supplied with blood is solely for the purpose of producing movement. In addition to the movements that we are accustomed to see, such as the motion of the arms, legs, and the head, there is the continued beating of the heart, the rhythmical contractions of the stomach and intestines, as well as movement in other organs. To all these should be added the wide range of movements in facial expressions. To accomplish these varied motions man uses more than five hundred muscles.

192. Action of a Voluntary Muscle. — By placing the hand on the front of the forearm and raising the hand toward the shoulder, the muscle under the hand becomes shorter, thicker, and firmer. At the lower end of this muscle, a strong cord can be felt as the forearm is lowered. This cord is the tendon that attaches the muscle to one of the bones of the forearm. The upper end of the muscle is covered by other muscles, but we know that it is attached to the shoulder blade by two tendons. This muscle is the biceps, and like all other arm and leg muscles consists of a central part, the belly. It has its origin on the shoulder blade by two tendons and is inserted on the radius bone by one tendon. When a voluntary muscle produces motion, the two ends of



Photographed by Henry W. Stiles.

FIGURE 201. — HIP AND THIGH MUSCLES.
To show the parts of a muscle and its attachment.

the muscle are drawn closer together and the belly becomes shorter, thicker, and firmer. The living muscle cells are the only parts that undergo any change in shape, while the living cells in the connective tissue sheaths and in the tendons remain unchanged in shape.

The voluntary muscles exist in the body, especially in the arms and legs, in bundles. One muscle is attached to the front surface of the arm, while a second muscle is attached to the back surface. The movements of the arm are brought about by the shortening of a muscle in every case, consequently a muscle which straightens the bent arm is one of several of the muscles that are known as *extensors*. The bending of the arm is accomplished by one or more muscles which are known as *flexors*. This same general classification of muscles applies to the leg and to the muscles of the trunk.

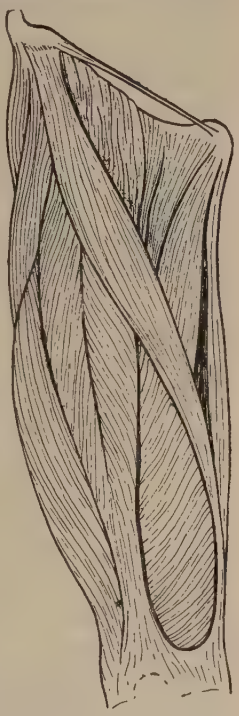


FIGURE 202. — MUSCLES OF UPPER LEG.

Note how they are arranged in bundles, which is an adaptation that enables the leg to be moved in various directions.

193. Nerve and Blood Supply of Muscles. — The muscles are richly supplied with numerous large and minute blood vessels and it is the blood that gives the deep red color to muscles. In recent years scientists have discovered that each muscle fiber is supplied with a fine branch of the main nerve that enters the muscle. This important fact enables us to understand how the nervous system is able to control the actions of our muscles.

194. Food of Muscles. — The blood flowing through the muscles carries food to the muscle cells. The most important

of the food substances used in the contraction of a muscle is grape sugar, or glucose. This sugar is formed in the body in digestion from starch and cane sugar. *Glycogen*, the stored-up sugar in the liver, is also used to furnish energy in contraction, but not until after it has become transformed into protoplasm. A small amount of fat is present in muscles and may be used up during their contraction. Under ordinary circumstances the protein foods do not furnish energy for contraction, but are used to repair the actual wastes that take place in the muscle cells as they do work.

195. Fatigue of Muscles. — After you have played hard for a time, you become tired and want to rest. You are tired or, to express it more scientifically, your muscles are fatigued. When you are taking your physical exercises, some of the movements make your arms ache, and you do not do them in good form. You are using muscles that do not get much exercise and they become quickly fatigued. You may continue to move your arm until it is impossible to move it any longer. In such cases of extreme fatigue not only are the muscles tired but also the nerve cells. Two things are involved in the fatigue process of a muscle: first, there is the using up of the food energy necessary for muscular contraction; and secondly, there is the accumulation of waste substances produced by the activity of the muscles.

196. Recovery from Fatigue of Muscles. — It is difficult to separate entirely a consideration of the muscles from the nervous system, as already explained, but some facts indicate in part what probably happens in the muscles as they are again made fit to do work. If the exhausted soldier is given a small amount of sugar while on the march, his fatigue is lessened. This is because sugar is quickly absorbed and is used by the muscles as a source of energy for contraction. This indicates that food will restore muscles. A second factor in relieving fatigue is rest, which gives the muscle cells time to recuperate by gradually building up the muscle

protoplasm, and removing wastes. As the energy required for the action of a muscle is mainly in the muscle protoplasm, there are changes that take place in it. Not all the energy of the muscle can be used in the contraction, and what remains is a waste substance that has to be removed. The removal of this waste is a large factor in relieving fatigue in muscles.

Under unusual conditions the muscles exhibit a remarkable endurance. A fast walker, taking 152 steps a minute, raises his body about twenty-three feet a minute. If he continues to walk at this rate for twenty-four hours, it is equivalent to lifting his body 33,120 feet. During the war there were many instances where men remained active for longer than twenty-four hours, but in the end there had to be a period of rest that was correspondingly long in order to permit the removal of all of the accumulated wastes and to restore the used-up parts. The principle thus remains the same whether the work done by a muscle is little or much. The muscle utilizes energy in contracting, and this energy must be supplied if the muscle is to work.

197. Importance of Exercise. — We are now in possession of the facts that enable us to understand the reason for physical training and some of the benefits to be derived from it. It is true that walking and running are forms of exercise, but they are both limited to but a part of the muscles of the body. People unaccustomed to a full set of "setting-up" exercises find themselves lame and sore after the first few times. This is because they exerted muscles that had been unused for a long time, and these muscles are not so strong as they ought to be. In a short time this lameness disappears and the morning exercises then give vigor and zest to the body.

These exercises thus serve to keep the bulk of our body, our muscles, in a healthy state. Such a condition has an important bearing upon our ability to do good work with

our brains because the mind works best when the rest of the body feels fit and full of energy. It is our duty to take our physical exercises seriously in order that we make our bodies as strong and vigorous as possible.

The recreative forms of exercise such as basket ball, tennis, baseball, football, and rowing are valuable for the general health and are good for the development of muscle. But we should not indulge in violent exercise except after careful training, which should always be preceded by a careful physical examination.

198. Use and Abuse of the Muscles. — All who have read about the results of the physical examination of the pick of the young men in America, during the recent World War, were startled by the large number that were declared physically unfit. This has caused us to inquire into the reasons why so many young people show such defects. Students planning to enter West Point are frequently rejected because their bodies are not well developed. And in any large group there are only a few who have their bodies sufficiently developed to enable them to qualify for our athletic teams.

In all of these cases of physical unfitness, each person has the same number of muscles, more than 500, attached to the same part of the skeleton. The deficiency then must consist in the training which each individual has given to these muscles.

The human body is not only very delicately adjusted or balanced but permits of a great variety of movements in the work performed. The muscles are subjected to varying degrees of strain, which have their influence not only on the organs of the chest and thorax, but upon the higher mental processes as well. Less energy is required in the correct use of the muscles than in the incorrect use of them. With the endless number of adjustments constantly taking place and in the wide variety of activities, everything that relieves

friction and strain upon the body is of great benefit. It is possible to refer only briefly to the use and abuse of the muscles in sitting, standing, and walking.

Sitting. — More and more of peoples' time is being devoted to work which is carried on in a sitting position, so that any suggestions leading to the saving of energy and lessening the fatigue of the muscles is very important. The correct sitting position is that with the trunk of the body straight, resting squarely on the hips, and not sliding down into the seat. The trunk should be kept at right angles to the long bones of the leg. It is easier to sit correctly in a shallow than in a deep seat. One can also sit correctly so far as the trunk is concerned and still become fatigued by bending the head too far forward at the neck.

Simple corrective exercises for improper posture in sitting can be taken with the body in proper sitting position by moving the trunk forward and backward, bending only at the hip.

Standing. — The correct positions of the body in standing and walking are similar, and the gain from the correct use of the muscles in these two natural movements is greater than that on sitting. The head should be well back, the chin drawn in, the chest raised, the abdomen flat, and the weight of the body borne on the balls of the feet. In such a position the head is nicely balanced with the least strain upon each of the muscles. The defects which incorrect position of the body causes require very definite exercises, as the weakness of the muscles is more pronounced in one region of the body than in another, such as the muscles of the back, neck, etc. To correct the standing posture the exercises known as standing at attention and standing relaxed are the most frequently used.

Walking. — Walking is a pleasurable form of exercise when the whole body is in correct position and the weight thrown forward on the ball of the foot. The feet should

point forward instead of at any angle. It is easy to practice correct walking by simply holding the body in proper standing posture, and then walking forward along a line, each step of the foot directed forward with the front foot close against the toes of the rear one.

199. Mental Attitude. — Every one who has witnessed well-trained men executing gymnastic or military drill has had his admiration stirred by the efficient manner in which they are using their muscles. And if we are really honest with ourselves, we will admit that we cannot handle our bodies as well. Just as soon as you acquire the correct use of your muscles, there is a feeling that you are in control of your body, and it affords a mental stimulus that no one should ignore.

Our mental attitude has much to do with our posture. How much straighter we stand when we are cheerful than when we are dejected! And our posture also reacts on our mental attitude. When we are gloomy and downcast, we can often make ourselves more cheerful by standing erect and taking a brisk walk in the fresh air, breathing deeply and throwing out our chests.

200. Hygiene of the Foot. — The human foot is an ingenious arrangement of bones, muscles, and tendons, whose function is to support the weight of the body. There are two arches in the foot, one located in the forward part, the *anterior metatarsal*, and the other running lengthwise and known as the *longitudinal arch* (Figure 203). Both of these act as shock absorbers and their perfect condition is essential to good feet. If, as often happens, one arch is depressed or broken down, we get what is called *flat foot*. Flat foot may be prevented by using a little care. It usually causes a feeling of unusual fatigue and weariness at night.

The proper method is to walk with the feet parallel, as if you were on snowshoes, not with the toes pointed out. Walking with the toes pointed straight ahead strengthens

the muscles and prevents flat foot. The exercises described in the following paragraphs can be taken for the purpose of correcting this deformity, for flat foot is a real deformity.

With the feet parallel, rise on the toes fifteen times the first night, sixteen the next night, and so on until you are doing the exercises fifty times. When you have reached

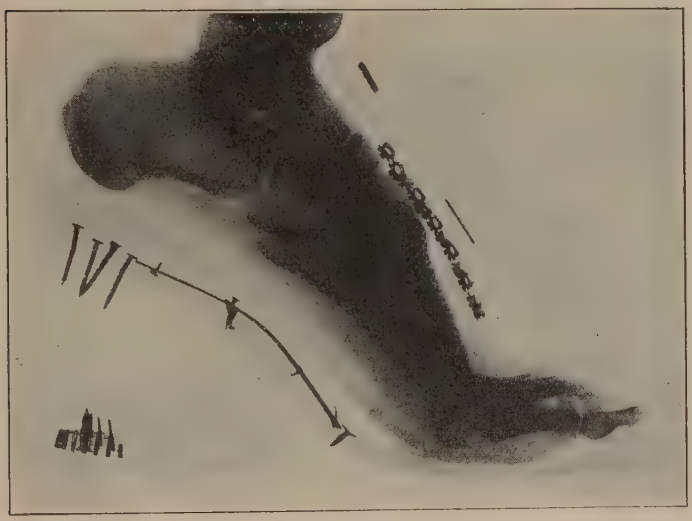


FIGURE 203. — X-RAY OF THE FOOT OF A GIRL WEARING A HIGH-HEELED SHOE.

The many layers of leather in the heel were fastened by means of glue. Notice the effect of raising the heel so high. It weakens the muscles on the back of the heel and places an unusual strain on the muscles of the arch of the foot. The wearing of such shoes is the source of much discomfort and is just one illustration of what one should not do who wishes to keep well. Compare with Figure 204.

fifty, decrease one a day until you are back to fifteen and then begin again.

The second exercise is to raise the toes off the floor so that you are standing on the heel. Do this fifty times.

The third exercise consists of standing on the outside of the foot, and while in this position trying to curl the toes back-

ward to meet the heel. Another excellent exercise is to pick up marbles with the toes. One or two days' trial of these exercises will convince you that there are muscles in your feet which you did not know were there. Keep at them, however, and you will soon be cured.

Arch supports do not cure flat foot. They act only as temporary splints, filling the shoe so that the foot is bound

FIGURE 204. — X-RAY OF THE FOOT OF A GIRL WEARING A SENSIBLE SHOE.

Note how differently the pressure comes on the parts of this foot as compared with that shown in Figure 203.

together and pinched. This often results in corns and callouses.

Corns, callouses, and bunions are caused by the use of too tight or too short shoes or stockings. It is not an uncommon experience when buying new shoes to have the clerk fit you to a short or narrow shoe. Right there your troubles begin. Demand a shoe which does not pinch your foot. Especially in the case of growing children, new shoes should be large enough to allow for natural growth.

OUTLINE

- Regions
  - Head
    - Cranial cavity
      - Brain
  - Trunk
    - Thoracic cavity
      - Lungs
      - Heart
      - Diaphragm
    - Abdominal cavity
      - Stomach
      - Intestine
      - Liver
      - Kidneys
      - Reproductive organs
- Skeleton
  - Skull
  - Spinal column
  - Ribs
  - Sternum
  - Long bones
    - Arm
    - Leg
  - Pectoral girdle
    - Clavicle
    - Scapula
  - Pelvic girdle
    - Sacrum
  - Functions and adaptations
- Bone and cartilage
  - Joints
    - Immovable
      - Sutures
    - Movable
    - Mixed
  - Broken bones
  - Structure of bone
- Muscles
  - Importance
  - Voluntary
  - Involuntary
    - Extensor
    - Flexor
  - Nerve and blood supply
  - Food
  - Fatigue
    - Recovery
  - Exercise
  - Use and abuse
    - Sitting
    - Standing
    - Walking
- Mental attitude
- Hygiene of foot
  - Flat foot
    - Prevention of
  - Exercises

SUMMARY

Man is able to move about as other animals. This he does by means of his muscles and skeleton, under the direction of the nervous system. The skeleton is covered by muscles and skin. Bones grow and are fed just like muscles or any other tissue in the body. The bones of the skeleton move by means of joints which are held in place by ligaments. Bones grow new bone, as is seen in the broken femur. There is a definite plan of structure to all bones.

The muscles are the flesh covered by the skin. The muscles are both voluntary and involuntary. Muscles are important both in the total

weight of the body and in the numerous movements that they produce. Each muscle causes movement through the action of its individual cells, which are supplied by nerves and blood vessels. The muscle protoplasm is supplied with food for contraction purposes and food to repair the wastes. Muscles become fatigued and require food, rest, and the removal of wastes in order to recover from this fatigue.

Physical training is valuable in helping to develop properly all the muscles of the body, in keeping the body well, and in making it the best body possible. Correct posture is important to health and depends partly upon mental attitude. Care should be taken of the feet, especially in the selection of proper shoes.

QUESTIONS

How does the skeleton of man compare with that of the crayfish? How do bones grow? Why do they grow? Where is there the most cartilage in our skeletons? What are joints? What is a sprain? How do broken bones heal? How does muscle differ from bone? How many kinds of muscles are there? What is the work of each? Why are muscles important? What is the relation of the nervous system to muscles? What is the importance of the blood vessels to the muscles? Explain how the different foods are used by muscles. What is the value of physical training? Why does good posture help you?

CHAPTER XVIII

RESPIRATION

Choke the air out of the lungs, and all is soon stagnation, cold and darkness.

— Oliver Wendell Holmes

201. Respiration is the life process in which oxygen is used in the cells of the bodies of plants and animals, and carbon dioxide eliminated from them. All animals carry on respiration, and in all the process is alike, although the various animals use different structures to secure the interchange of oxygen and carbon dioxide. The fish has special organs, the gills, while the frog and man have lungs.

Student Report on Respiration

	Get Oxygen		Get Rid of Carbon Dioxide		Breathe Through				
	Water	Air	Water	Air	Skin	Gill	Lung	Air Tubes	
Amœba									
Crayfish									
Fly									
Toad									
Bird									
Man									

202. Human Organs of Respiration. — In man air enters the nose and passes into the windpipe or trachea (trā′kē-ȧ). The opening into the windpipe is covered by the *epiglottis* (Greek, *epi*, upon; *glotta*, tongue), which is raised during

breathing and closed when food is swallowed. The windpipe divides into two branches, one entering each lung. Each branch is called a *bronchus*. The windpipe and bronchi are the air passages which carry air to the lungs. These passages are kept open by numerous stiff cartilage rings, which, in the trachea, are not entirely complete on the side of the esophagus, and in the smaller tubes even less so.

As each bronchus enters the lung, it divides into branches which in turn branch out again and again, until the entire lung is penetrated in all its parts by these passages. Finally each branch ends in a small pouch-like sac called an *air cell* or *air sac*. The walls of the air cells are thin, and the cells themselves are surrounded by minute branches of the blood vessels. It is estimated that the highly folded condition of the walls of the bronchi make a surface larger than the entire surface of the body. All these thin walls of the lungs and blood vessels are adapted to the passage of oxygen into the blood.

FIGURE 205. — THE LUNGS AND HEART.

Note the branches of the bronchus and blood vessels on the right side.

The lungs of man, then, consist of two large bronchial air tubes, many branches of the bronchi, air cells, blood vessels, and a few nerves, all bound up into two definite bodies (Figure 205).

The *voice box* or *larynx* (lăr′ĭnks) is found just below the opening into the windpipe and is called "Adam's apple." The larynx is formed by several large pieces of cartilage lined with a mucous membrane. On the inside of the larynx project two folds of elastic tissue which are called the *vocal cords*.

203. Breathing. — The lungs are elastic and can be squeezed like a sponge. *Inspiration* is the term applied to the taking of air into the lungs, and *expiration* to the forcing out of air.

When air is drawn into the lungs, the chest expands by pulling the ends of the ribs upward and outward and by pulling down the diaphragm, the horizontal muscle which divides the lung cavity from the abdomen (Figure 186). Thus the chest cavity is enlarged and air is sucked into the lungs. The process of inspiration requires that the muscles of the

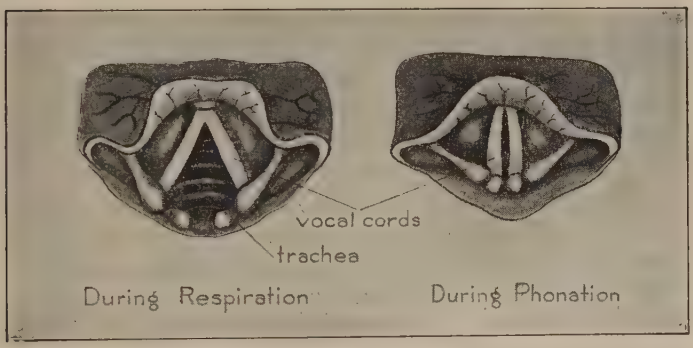


FIGURE 206. — VOICE BOX OR LARYNX.

chest do a considerable amount of work, as the cartilages attached to the ribs must be bent and the walls of the abdomen stretched.

In expiration the air passes out gently. The muscles that have caused the expansion of the chest relax and the ribs sink back into their former position. As the muscles of the abdomen contract, the organs in the abdominal cavity press upward and the diaphragm arches forward into the chest cavity.

When we breathe naturally only a small part of the air in the lungs is exchanged at each inspiration and expiration, but

by breathing deeply a few times we can remove the larger part of the air from the lungs and replace it with fresh air.

The natural rate of breathing is about eighteen times a minute, but the rate is higher in persons with a small lung capacity. Exercise increases the rate of breathing. Explain why exercise out-of-doors is better for us than that taken indoors.

All the air passages are lined with cells bearing numerous cilia (Figure 207), and these cilia are constantly in motion. Their work is to carry toward the mouth the particles of dust and other foreign materials brought in by the air. This foreign matter is removed when we cough or clear our throats. Explain why clean air is better for us than foul air.

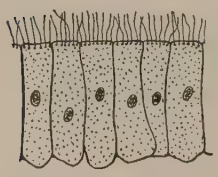


FIGURE 207. — CILIATED EPITHELIUM.

Such cells line our bronchial tubes. Explain their work.

The purpose of respiration is to take the air, rich in oxygen, into the lungs, where the oxygen passes into the blood as the capillaries penetrate the walls of the lungs, and to give off the waste carbonic acid gas that has come from the cells of the body. Thus respiration is a twofold process, the supplying of the living cells of the body with oxygen and the removal of wastes from the blood. The air that is inhaled contains a small amount of carbonic acid gas, but the proportion is much smaller than in the exhaled air. It is well to keep in mind that green plants are constantly, during the daytime, using carbonic acid gas in manufacturing starchy foods and giving off oxygen so that the air is being made better for animals and man to breathe, while at the same time these green plants are storing up food for animals, including man.

204. Hygienic Habits of Breathing. — The passages of the nose occupy a much larger space than one would suppose. This subdivided surface in the nasal passages is covered with a mucous membrane. The cells in this membrane are

richly supplied with blood, which enables them to secrete a liberal supply of moisture. We become more conscious of their work when we first come down with a cold and the nose "runs." When we have a cold, these cells are more active than usual.

As the air passes through the nasal passage three things usually happen: First, a large proportion of the dust particles in the air are deposited; second, the air is warmed nearly to blood heat; and third, it receives moisture from the mucous membrane. Each of these three changes is important. If we breathe through the mouth, these changes have to take place in the passages of the lungs, where the accumulation of dust particles and disease germs is injurious.

205. Systematic Exercise. — If we keep our bodies in correct posture, but little need be said about breathing exercises. A great deal has been written about the value of deep breathing, but we all know that it is not necessary to continue to do this all the time. There is no question that it is desirable to be able to breathe deeply and to have a large chest if for no other reason than that it gives the heart more room to do its work. Lazy habits of breathing tend to weaken the muscles of inspiration, and the result is that only a part of the lungs is used. Regular exercises, then, which develop the chest muscles are valuable in breathing. In a well-developed body, involuntary breathing suffices for everything but unusual activity, such as running and similar strains, which demand that the body be supplied with more oxygen.

The effect of proper exercises on the chest, then, is to develop the muscles thus used. The chest is larger under such conditions and there is more room for the lungs to expand. They are able to hold more air. This in turn renews the air more frequently in the air sacs, which are not supplied with muscles but consist of a very simple layer of cells. Exercise has no effect on their size and activity. Muscles, also, are

present in the walls of the lungs, tracheæ, and bronchi and indolent breathing leaves parts of the lungs inactive so that the muscles in these portions become sluggish. Here again exercise plays an important part in helping the lungs do their best work.

206. Tight Clothing and Breathing. — The normal movements in breathing permit the ribs to be elevated as air is pumped into the lungs. Anything that interferes with these normal movements makes it more difficult to get the required amount of oxygen into the lungs. Wearing tight clothing around the chest retards these natural movements and prevents the strong development of the muscles of this region. The continued practice of wearing such clothes makes one short of breath and prevents any great amount of muscular activity. Unless loose clothing is worn during exercise, the muscles used in respiration are not benefited by the exercise.

207. Suffocation and Artificial Breathing. — When the body is deprived of a sufficient supply of oxygen, suffocation results. This may be brought about by confining a person to a small, air-tight inclosure, by inhaling poisonous gases, and by drowning. Whatever may be the cause of suffocation, the person should be at once brought into fresh air.

Persons suffering from suffocation can often be revived by artificially moving the muscles of the chest so as to imitate as closely as possible the normal breathing movements. There are several well-known methods, of which the *Schaefer method* of artificial breathing is regarded as one of the best. The patient is placed with his face downward, having the forehead resting on one arm. The person attempting to stimulate natural breathing should get astride of the patient's legs and place his hands on each side of the patient's body opposite the lower ribs. He should press down and in and then relax the pressure. This simple series of movements

should be repeated about fifteen times a minute. The pressure thus exerted will help to force the water from the lungs in the case of drowning. It imitates, as well as one can, the natural breathing movements, and should be continued, if necessary, for several hours.

208. Uses and Necessity of Oxygen. — It has been repeatedly stated in describing the life functions of animals, and will be repeated in the description of the life of plants, that oxidation is one of the fundamental and vital processes. The life activities of man conform to those in animals and plants. His body is composed of millions of cells, each one of which must have oxygen in order to live. The blood vessels (see page 349) carry the oxygen to the cells. In the lungs, the taking up of oxygen is important only to supply the blood with enough oxygen to furnish the necessary amount for these numerous cells. When we undertake excessive exercises, the oxygen in the tissues becomes exhausted and we have to stop and rest — in fact, we wait for a fresh supply of oxygen to be carried to the cells. At the same time one must keep in mind the importance of getting rid of the waste, carbon dioxide, as its accumulation in the body is a large factor in fatigue.

We get an idea of the value of oxygen if we study mountain sickness. The amount of oxygen at high elevations is much less than on lower levels, and is especially noticed by those who go to great heights either on lofty mountains or in airplanes. This lack of oxygen usually tends to lessen the amount taken in by the lungs and the result is felt in the nervous system. When there is a deficiency in the supply of oxygen there is one outstanding result, the formation of lactic acid. This is usually followed by nervous irritation, sickness, and pain in the head. The result is similar to that produced by excessive indulgence in alcohol. People who undertake to see how high they can go in an airplane take a supply of oxygen with them.

209. Ventilation. — Associated with the question of breathing is the problem of supplying our homes with fresh, pure air. Every one feels better after a walk in the open air. To have plenty of fresh air in our rooms and to remove the carbon dioxide is a hard problem. One of the difficulties is to get the air down to the breathing line and not stir up the dust on the floor. Figures 208 and 209 show the best plans for ventilating a room. They are adapted to the two common methods of heating, hot air and steam or hot water. They show the course taken by the currents of fresh air entering the room at night with the window open, and in the daytime with it shut.

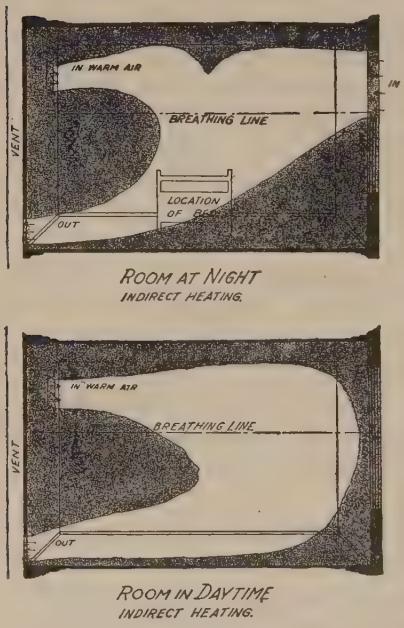


FIGURE 208. — HOT-AIR HEATING.
By Earl Hallenbeck.

210. Air Currents, Temperature, and Humidity. — The biological explanation of air currents and humidity centers in our understanding of temperature. Wherever man is found, whether he lives in the icebound North or the Tropics, in winter or summer, his temperature remains the same, independent of external conditions; in short, he is warm-blooded. All of the life processes contribute to maintaining this condition, and it is not correct to say that oxidation alone is responsible. When we speak of the temperature of man, reference is made to the internal

temperature and not to that of the surface of the skin. The temperature of the skin is influenced by the varying changes in the air, and does not approach that of the blood except when the blood vessels beneath the skin become enlarged and the heat is prevented from escaping into the air.

The temperature of the body is measured by the clinical thermometer. Some such instrument is necessary because we cannot tell by our feelings what our temperature really is. In the case of such diseases as typhoid and other fevers, the normal temperature of 98.6 degrees Fahrenheit, or 37 degrees Centigrade, is increased. Our bodies are burning up more energy than they should, so that it becomes very important to know their exact temperature. There is a slight daily fluctuation in the temperature of a well person. It is lowest early in the morning and usually highest sometime in the afternoon or early evening.

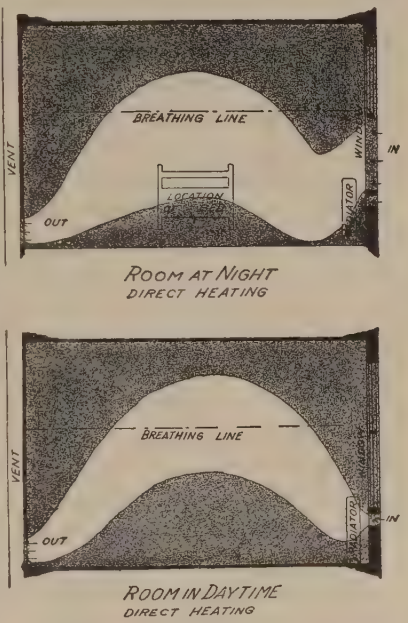


FIGURE 209. — STEAM HEATING.
By Earl Hallenbeck.

We are constantly giving off heat from our bodies. We say that the brick wall or stone steps are cold, that iron is colder than wood, but we really mean that heat passes more rapidly from the skin to one substance than to another. Heat also passes from the body into the air. One of the conditions

that hinders this escape of heat is the amount of moisture in the air, its humidity. If the air that comes in contact with the skin holds all of the water that it can, then it will not take up any more water unless it becomes somewhat heated.

When there is a great deal of water in the air, we speak of high humidity. If the humidity is high and at the same time the temperature is above normal as sometimes happens in the summer, then we are very uncomfortable. Under such a combination of conditions, the relief from the high temperature is hindered because we do not give off as much heat from our bodies, that is, the saturated air does not take up heat as fast.

The perspiration that escapes from the body usually evaporates so rapidly that we are not aware of it. This is one means by which our feeling cold or warm is regulated. Air currents coming in contact with the skin assist in removing the heat of the body. In a smaller way, the same results are brought about in exercise of all kinds. When we are resting, the air close to the skin and under our clothes is warm and heavily laden with moisture. Just as soon as the parts of the body are moved in running, riding, and even walking, a breeze is felt. One can stand still and swing the arms and the air next to the skin is changed. The air next the body, which has become warm and moist, is replaced a moment later by cooler and drier air.

211. Clean Air. — A great deal has been written about "clean air," "bad air," "stuffy air," and many experiments have been made to see just what makes us uncomfortable. When a room seems stuffy or close our discomfort is usually due to overheating of the skin. The surface of the body is generally kept comfortable by the air currents which pass over it and aid in the evaporation of perspiration. In a confined space, where there is a lack of movement in the air it tends to become warm and humid. Thus moisture is not taken promptly from the skin and its temperature rises. The most effective precaution to be taken is to keep a room

comfortably cool and to have some circulation of the air. This is the reason that an electric fan adds to our comfort though the air has not been changed so far as the oxygen and carbon dioxide are concerned.

212. Diseases of the Respiratory Tract. — The most common of these diseases is a cold located in the nose and throat. The nasal passages become clogged with mucus which contains many germs. These germs are widely distributed in sneezing.

Diphtheria is a germ disease which is located in the throat and nose. For many years diphtheria was one of the most deadly of our diseases, but through the use of the diphtheria antitoxin the danger has been greatly reduced.

Bronchitis and pneumonia are germ diseases located in the bronchial tubes of the lungs. Pneumonia is a frequent cause of death, especially among aged people.

Tuberculosis of the throat and lungs is a widely distributed disease which causes many deaths each year. See page 408.

Adenoids are the result of an enlargement of the pharyngeal tonsil. The commonest result is the stopping of the nasal passage. Almost all mouth-breathing children have adenoids. These should be removed not only because they prevent the natural use of the nasal passage but because they often cause deafness.

OUTLINE

- Respiration defined
  - Human organs
    - Nose
    - Windpipe
    - Lungs
  - Breathing
    - Inspiration
    - Expiration
    - Hygienic habits
  - Exercise
  - Tight clothing
  - Suffocation
    - Artificial breathing
      - Schaefer method
    - Necessity of oxygen
      - Mountain sickness
    - Ventilation
      - Air currents
      - Temperature
      - Humidity
      - Clean air
    - Diseases
      - Of throat
      - Of lungs

SUMMARY

All living things require oxygen, which in man and the higher animals is carried by the blood to the cells of the body. The parts which man uses in breathing are more highly developed than in any other animal. The voice box, the larynx, by means of which he is able to make a wide variety of sounds, is located at the top of the trachea. Oxygen plays a most important part in keeping the body of man warm through oxidation. Proper ventilation enables the body to secure sufficient oxygen and so assists in fighting the various diseases of the respiratory tract.

QUESTIONS

Compare the organs of respiration in the animals that you have studied such as crayfish, fish, frog, and man. In what important point do all agree? What is the difference between gills and lungs? Where do air-breathing animals get their oxygen? Where do water-breathing animals get their oxygen? What is the importance of exercises in developing our chest muscles? In making us more comfortable?

CHAPTER XIX

FOODS, STIMULANTS, AND NARCOTICS

For what can power give more than food and drink?
— DRYDEN

213. What Makes Us Go? — One of childhood's earliest questions suggested by the first mechanical toy is, "What makes it go?" Later the same query is applied to his own body. We are still asking, "What makes us go?" Nearly every magazine has a patented food preparation that guarantees to make man go better than do the ordinary foods. There is but one method of approaching this problem, and that is through a study of the relation of energy to life processes. What are our resources? Under what limitations and regulations can we use these resources?

The body goes because it is furnished with energy from the food eaten. The source of the energy for bodily movement, growth, and repair of tissue is in the food molecules, which in turn derive their energy from the process by which they are manufactured. Review the significance of photosynthesis (page 37) in this connection.

214. Nutrients in Common Foods. — The nutritive materials produced and consumed fall into the following classification:

(*a*) *Primary Foods.* — These include (1) all plant materials used as human foods (potatoes, corn, berries), and (2) all animal products (fish, oysters) where the animal gets its nourishment from some source other than primary feeds and fodders.

Primary feeds and fodders are the plant materials used for the nourishment of domestic animals and derived from harvested grains and manufactured feeds.

(*b*) *Secondary Foods.* — These consist of all edible parts and products of animals which have been nourished with the primary feeds and fodders (honey, eggs, milk, meats).

FIGURE 210. — SCHOOL CHILDREN RAISING PRIMARY FOODS.

215. Food. — Food may be defined as that which when taken into the body builds up tissue or yields energy. Foods are classified as *proteins* (prō′tē-ĭns), *carbohydrates* (kär-bō-hī′drāts), *fats*, *mineral matter*, and *vitamins* (vī′-ta-mĭns). This classification is made whether we study the foods of a plant, an animal, or of man. Scientists are able to tell to which class meat, bread, oatmeal, milk, and all other foods belong by finding out the chemical composition of each.

Definite chemical tests tell us to which of these classes any given article of food belongs. In general the proteins and minerals are necessary for the growth and the repair of the

body; the carbohydrates and fats furnish heat to keep the body warm and energy for muscular work; the vitamins are body-regulators. The unused fat is stored up as fatty tissue.

All classes of food are found in the various foods obtained from plants. Some, like honey, are nearly pure carbohydrate, while the English walnut contains, in addition to fat, a large quantity of plant protein. Animal foods can furnish us with only proteins and fats. In primitive times man used a restricted diet and led an active out-of-door life. To-day man spends much of his time indoors and lives on a mixed and varied diet. The question of how much to eat is a modern problem, and on its solution depend our health, length of life, and energy for work.

Food as purchased contains:

- Edible portion (*e.g.*, flesh of meat, yolk and white of eggs, wheat, flour, etc.)
  - Water.
  - Nutrients
    - Protein.
    - Fats.
    - Carbohydrates.
    - Mineral matter.
    - Vitamins.
- Refuse (*e.g.*, bones, entrails, shells, brain, etc.)

Alcohol is made up of carbon, hydrogen, and oxygen. All proteins contain nitrogen in addition to these three. Because alcohol contains no nitrogen, it cannot be used as a food.

USES OF NUTRIENTS IN THE BODY

Protein (*e.g.*, white (albumen) of eggs, curd, casein (kā′sē-in) of milk, lean meat, gluten of wheat, etc.)	Forms tissue	All serve as fuel to yield energy in the form of heat and muscular power.
Fats (*e.g.*, fat of meat, butter, olive oil, oils of corn and wheat, etc.)	Are stored as fat	
Carbohydrates (*e.g.*, sugar, starch, etc.)	Are transformed into fat	
Mineral matter (ash) (*e.g.*, phosphates of lime, potash, soda, etc.)	Shares in forming bone, assists in digestion, etc.	
Vitamins found in milk, eggs, meat, fruit, vegetables, and whole grains	Help keep people well and promote the growth of children.	

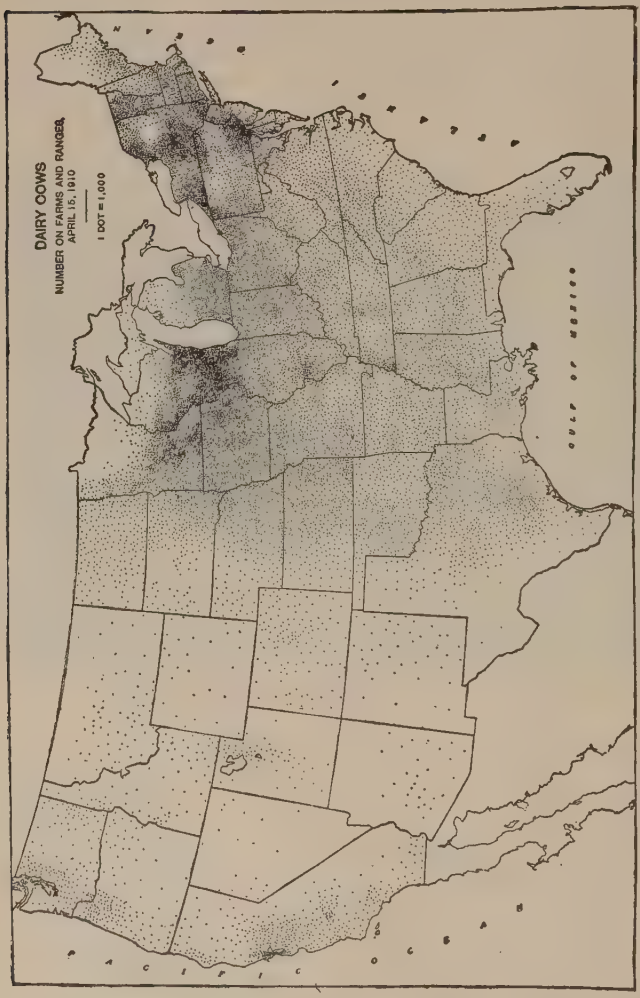


FIGURE 211.—DISTRIBUTION OF DAIRY COWS IN THE UNITED STATES.

Economy in the Purchase of Foods. — Of course it is expensive to buy fresh peaches or strawberries at Christmas time. But by purchasing fruits and vegetables which are "in season," and by studying the local markets to see what is raised in the neighborhood, it is possible to secure fresh materials for a well-balanced diet at a reasonable price.

216. Milk. — Milk and cream make up about one sixth of the weight of all of the food eaten by the average American family. Wherever conditions are favorable for cattle raising we find the inhabitants using cow's milk, but in those regions of the world where cows do not thrive, such as in the hilly districts of Europe, goat's milk is used. In some parts of India buffalo's milk is common, while in South America the llama furnishes the milk. Camel's milk in desert countries and mare's milk on the steppes of Russia are as natural to the inhabitants of these places as cow's milk is to us.

AVERAGE COMPOSITION OF MILK OF VARIOUS KINDS

KIND OF MILK	WATER	PROTEIN			FAT	CARBOHYDRATES (MILK SUGAR)	MINERAL MATTER	FUEL VALUE PER POUND
		Casein	Albumin	Total				
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Calories*
Woman	88.3	—	—	1.2	3.3	7.0	0.3	285
Cow	87.0	2.8	0.5	3.3	4.0	5.0	.7	315
Goat	85.7	3.5	1.0	4.5	4.7	4.4	.8	355
Sheep	81.9	—	—	5.3	7.3	4.7	.9	480
Buffalo (Indian)	82.2	4.3	.5	4.8	7.5	4.8	.8	480
Camel	87.1	3.5	.4	3.9	2.9	5.4	.7	285
Llama	86.6	3.0	.9	3.9	3.2	5.6	.8	305
Reindeer	67.2	8.4	1.5	9.9	17.1	2.8	1.5	930
Mare	90.6	1.3	.8	2.1	1.1	5.9	.4	190
Ass	90.1	.8	1.1	1.9	1.4	6.2	.5	205

From U. S. Department of Agriculture, Farmers' Bulletin No. 1359.

The milk from all these animals is similar except in taste. There is a large per cent of water in milk. On the average, commercial milk contains 87 per cent of water and 13 per cent solids. The solids consist of proteins, carbohydrates,

fats, and a variety of mineral substances. The amount of these several products is well shown in the previous table.

Milk is unlike most of our foods because it contains no refuse or indigestible material. Milk is valuable, then, because, first, it contains materials that children need for growth; second, materials that young and old alike need for the repair of the body machinery, and third, materials that all need for fuel, to provide them with heat and with the energy necessary for work. We should not make the mistake, however, of thinking that because milk has these valuable ingredients that it can serve satisfactorily as the only food for a grown person or even a child after the nursing age. One would need to drink five or six quarts a day to meet the needs of school age, and this quantity would supply too much protein. Iron also is needed in greater abundance than is furnished by milk. Other foods, therefore, are necessary to supplement milk.

217. Green Vegetables and Fresh Fruit. — While milk is especially valuable for the variety of nutrients it contains, the importance of vegetables and fruits should not be overlooked. Green vegetables contain a large proportion of mineral matter. For very young children, spinach, asparagus tips, string beans, and peas, when well cooked and mashed, are highly nutritious. For older children and grown-ups, potatoes, beets, carrots, cauliflower, and squash are valuable.

Fresh fruits are especially good for children. There is much truth in the old saying, "an apple a day keeps the doctor away." It is now possible to secure apples, oranges, bananas, and many other delicious fruits at almost any season of the year.

218. Meaning of Calorie. — Heat is a form of energy, and one of the reasons for taking food is to keep up the supply of this energy. The more work a person does the more energy he uses, but even a resting body uses some energy, for the

heart beats and the muscles of the chest move. The amount of this form of energy a person uses is measured by a unit of heat named the *Calorie* (kăl′ŏrĭ).[1] A Calorie represents the amount of heat required to raise the temperature of a pint of water about four degrees Fahrenheit. A man in rising from a chair, walking eight feet, and returning to the chair uses about one Calorie of energy.

The term Calorie just defined is now used throughout the civilized world as the common unit of measurement for food energy. Through the studies of experts it has been determined how many Calories are necessary to keep the human body from starvation, how many more must be added if the body is to do light physical work, and how many more if heavy manual labor is done.

219. Diet for Different Occupations. — Man's food requirement varies according to occupation and climate. One must keep in mind that our bodies require energy to grow new cells and to keep the old ones in repair; to keep the body at a constant temperature winter and summer; and to furnish energy for muscular activity, which often requires more energy than to carry on growth and maintain a constant temperature. To meet these needs of every human being a variety of foods is needed.

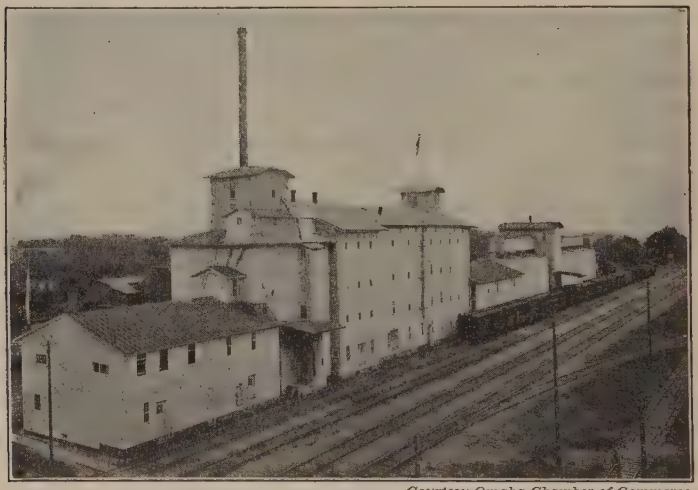
More energy is required in an active occupation and more heat in a cold climate. The Calorie is the unit for measuring the heat which is a form of energy. The daily Calorie needs for certain persons are approximately:

For a workingman	3500 to 4000
For an active woman	2800 to 3000
For a sedentary man	2200 to 2800

[1] Note that this Calorie should always be spelled with a capital C. This is to distinguish it (the greater Calorie) from the lesser calorie, which is used in physics as the unit of heat. The lesser calorie is the amount of heat that will raise one gram of water one degree centigrade. The greater Calorie is equal to 1000 lesser calories.

For a sedentary woman	1800 to 2300
Youth 14 to 16 years	1500 to 3200
Active soldier	4000

220. Vitamins. — This word is so new that it is found only in recently published dictionaries. From 1917 on there have been numerous scientific contributions and a few books on the subject of vitamins. The heralded importance of



Courtesy Omaha Chamber of Commerce.

FIGURE 212. — FLOURING-MILL WHERE WHEAT IS TURNED INTO FLOUR.

One of these large mills in Minneapolis has the equipment to turn out sixteen thousand barrels of flour every twenty-four hours.

these substances as a necessary part of our foods and as a protection against certain diseases was quickly taken up by the manufacturers of special food-products, until one hears this technical term used on every side.

The word *vitamin* was coined by a Polish scientist, Casimir Funk, who believed that there was a special vital substance in foods that was related somehow to the proteins. As we have come to learn more about these mysterious bodies, the

word vitamin has ceased to have its first meaning but is retained because no better term has been suggested to take its place. So for the present we will use the expression vitamin A, vitamin B, and vitamin C for the three best known vitamins.

VITAMINS IN FOODS

	"A"	"B"	"C"		"A"	"B"	"C"
Bread, white (water)	?	†	—	Tomatoes (raw or canned)	††	†††	†††
" " (milk)	†	†	?	Beans, kidney	*	†††	*
" whole wheat (water)	†	††	?	" navy	*	†††	—
Bread, whole wheat (milk)	††	††	?	" string (fresh)	††	††	††
Barley (whole)	†	††	—	Cabbage, fresh, raw	†	†††	†?
Corn, yellow	†	††	—	" cooked	†	††	†?
Oats	†	††	—	Carrots, fresh, raw	††	††	††
Meat, lean	— to †	†?	†?	" cooked	††	†	†
Beef fat	†	—	—	Cauliflower	†	††	†
Mutton fat	†	—	—	Celery	*	†	*
Pig kidney fat	††	—	—	Cucumber	*	†	*
Oleomargarine	†	—	—	Dandelion greens	††	††	†
Liver	††	††	†	Eggplant, dried	*	††	*
Kidney	††	††	†?	Lettuce	††	††	†††
Brains	†	††	†?	Onions	*	††	††
Sweetbreads	†	†	*	Parsnip	—?	††	*
Fish, lean	—	†	*	Peas	††	††	†?
" fat	†	†	*	Potatoes (boiled 15 min.)	*	††	†?
" roe	†	††	†?	Potatoes (boiled 1 hour)	*	††	†?
Milk, fresh	†††	††	†V	Potatoes (baked)	*	††	†
" condensed	†††	††	†V	Sweet potatoes	††	†	*
" dried (whole)	†††	††	†V	Radish	*	†	*
" skimmed	†	††	†V	Rutabaga	—?	††	†††?
Buttermilk	†	††	†V	Spinach, fresh	†††	†††	*
Cream	†††	††	†V	" dried	†††	††	*
Butter	†††	—	—	Squash, Hubbard	††	*	*
Cheese	††	*	*	Turnips	—?	††	*
Cottage cheese	†	*	*	Apples	†	†	†
Eggs	††	†	†?	Bananas	†?	†?	†
Almonds	†	†	*	Grape juice	*	†	†
Coconut	†	††	*	Grapefruit	*	††	††
Hickory nuts	*	††	*	Lemon juice	*	††	†††
Peanuts	†	††	*	Orange juice	†	††	†††
Pecans	*	†	*	Prunes	*	†	—
Walnuts	*	††	*	Raspberries (fresh or canned)	*	*	†††

† contains the Vitamin
†† good source of the Vitamin
††† excellent source of the Vitamin
— no appreciable amount of the Vitamin
? doubt as to presence or relative amount
* evidence lacking or insufficient
V variable

In our regular diet these several vitamins are always present, for beef, mutton, liver, milk, germinated cereals, fresh cabbage, tomatoes, string beans, carrots, and lettuce contain all three vitamins; while eggs, whole wheat, beans, spinach, and nuts are especially rich in vitamins A and B. Onions, lemons, oranges, raspberries, and apples contain vitamin C. This list of common foods which contain an adequate supply of vitamins for all ordinary conditions, should convince us that patented preparations are wholly unnecessary.

What is the use of vitamins in our diet? This question cannot be answered satisfactorily. Three possible explanations have been offered: (1) that vitamins aid in digestion; (2) that they stimulate activity in the cells; (3) that they supply certain chemical groups that the body needs but cannot itself manufacture.

Two diseases are now believed to be definitely identified with the deficiency of vitamins in the diet. Beriberi, a disease involving a general paralysis of the system, is due to the lack of vitamin B; while scurvy is caused by lack of vitamin C.

The previous table gives a list of our principal articles of food and shows the different vitamins present in them.

221. Food Groups. — In the classification of foods given on page 27 into proteins, carbohydrates, fats, mineral matter, and vitamins, the arrangement is made upon their chemical composition because foods do not grow as proteins or fats. The foods that we eat are often composed of all these. There are five food groups which are arranged chiefly on the proportionate amounts of proteins, sugars, or fats. These are shown in the table on the following page.

A well-balanced diet contains a proper proportion of these five food groups. One food from each of these groups should be used each day. It is impossible to prescribe an exact diet for every one, as it should vary with the age, weight,

health, occupation, and location of the individual. The variation, however, is largely in the quantity rather than in the kind used.

The following table shows the food groups and their relative importance, together with the daily amount needed by the average man.

Food Groups	Purposes	Amount Needed Daily by a Man at Moderate Muscular Work
No. 1. — Fruits and vegetables.	To give bulk and to insure mineral and body-regulating materials.	1½ to 3 pounds.
No. 2. — Medium-fat meats, eggs, cheese, dried legumes and similar foods, milk.	To insure enough protein.	8 to 16 ounces (4 ounces of milk counting as 1 ounce).
No. 3. — Wheat, corn, oats, rye, rice, and other cereals, potatoes, sweet potatoes.	To supply starch, a cheap fuel, and to supplement the protein from Group 2.	8 to 16 ounces (increasing as foods from Group 2 decrease).
No. 4. — Sugar, honey, sirup, and other foods consisting chiefly of sugar.	To supply sugar, a quickly absorbed fuel, useful also for flavor.	1½ to 3 ounces.
No. 5. — Butter, oil, and other foods consisting chiefly of fat.	To insure fat, a fuel, which also adds to the richness of food.	1½ to 3 ounces.

It is difficult for some of us to realize that our foods fall into such few groups as in the table above, since nearly every magazine that we examine is advertising some new breakfast food or some special brain food. For many of us a variety in our daily menu has become almost a necessity and we think ourselves restricted if limited to five groups. This is equally true of those who claim to be vegetarians as well as those who are accustomed to derive their protein energy and carbohydrate energy from animal as well as plant foods.

The following table [1] shows the consumption of proteins in the United States. Why should the large number of statis-

Group	Average for Six Years, 1911–12 to 1916–17			For 1917–18		
	Absolute Consumption of Protein (Metric Tons)	Percentage Consumption	Cumulated Per Cent	Absolute Consumption of Protein (Metric Tons)	Percentage Consumption	Cumulated Per Cent
Grains . . .	1,316,140	36.01	36.01	1,303,348	34.44	34.44
Meats	964,117	26.38	62.39	945,277	24.98	59.42
Dairy products .	744,784	20.38	82.77	788,969	20.85	80.27
Poultry and eggs	246,178	6.74	89.51	285,413	7.54	87.81
Vegetables . .	214,404	5.87	95.38	248,772	6.57	94.38
Fish	84,852	2.32	97.70	102,022	2.69	97.07
Oils and nuts .	57,839	1.58	99.28	85,021	2.25	99.32
Fruits	24,965	.69	99.97	23,621	.62	99.94
Oleomargarine .	838	.02	99.99	1,808	.05	99.99
Sugars	455	.01	100.00	439	.01	100.00
Total . . .	3,654,572	100.00	—	3,784,690	100.00	—

Figure 213. — Table of Protein Consumption.

tics in Figures 213 and 214 and those in the tables on pages 310 and 311 be included in an elementary text-book of biology? If any one had been confronted with the question, "How much corn, or oats, or molasses, or fish, or milk, or nuts, or fruit is consumed each year in the United States as food," no one could have given more than a rough guess until Professor Raymond Pearl of the New School of Hygiene of the Johns Hopkins University made this exhaustive study. The question is a fair one and it is very important that we be able to give a correct answer. The study of all the foods used by man has not been made; but for some twenty of the great groups we are in a position to present such tables as these, which are more accurate than any others ever compiled.

[1] The following four tables are taken from the Proceedings of the American Philosophical Society, Volume LVIII, November 3, 1919.

On the basis of such figures it is possible to discuss intelligently the relative importance of the great groups, like the

Group	Average for Six Years, 1911–12 to 1916–17			For 1917–18		
	Absolute Consumption of Fat (Metric Tons)	Per-Centage Consumption	Cumulated Per Cent	Absolute Consumption of Fat (Metric Tons)	Per-Centage Consumption	Cumulated Per Cent
Meats	2,591,613	50.66	50.66	2,602,187	47.48	47.48
Dairy products .	1,405,918	27.49	78.15	1,505,129	27.46	74.94
Oils and nuts .	623,385	12.19	90.34	781,461	14.26	89.20
Grains . . .	203,585	3.98	94.32	227,807	4.16	93.36
Poultry and eggs	173,349	3.39	97.71	175,220	3.20	96.56
Oleomargarine .	57,965	1.13	98.84	125,024	2.28	98.84
Vegetables . .	21,126	.41	99.25	27,864	.51	99.35
Fruits	20,242	.49	99.65	17,866	.33	99.68
Fish	18,096	.35	100.00	17,381	.32	100.00
Sugars	0	0	100.00	0	0	100.00
Total . . .	5,115,279	100.00	—	5,479,939	100.00	—

Figure 214. — Table of Fat Consumption.

grains and the vegetables, in the nutrition of a people. We can now calculate *the total national food bill.*

One of the important conclusions is that the annual consumption is quite uniform from year to year. No matter how much production, nor how much variation there is in the exports and imports, the people of the United States eat about the same amount each year.

If these and the other statistics in this remarkable contribution are studied, it is easily shown just where the proteins, fats, and carbohydrates come from. Thus the American people get over one half of their protein from animal sources exclusive of fish. Such a conclusion indicates the great importance of maintaining our animal herds intact. Eighty-two per cent of the fat comes from animal source; while but five per cent of the carbohydrates are of animal origin.

The table below shows the consumption of carbohydrates in the United States.

Group	For the Six Years, 1911–12 to 1916–17			For 1917–18		
	Absolute Consumption of Carbohydrate (Metric Tons)	Percentage Consumption	Cumulated Per Cent	Absolute Consumption of Carbohydrate (Metric Tons)	Percentage Consumption	Cumulated Per Cent
Grains . .	9,208,939	56.1073	56.1073	9,291,445	54.2224	54.2224
Sugars . .	4,193,095	25.5473	81.6546	4,374,194	25.5266	79.7490
Vegetables .	1,421,851	8.6629	90.3175	1,844,682	10.7651	90.5141
Dairy products .	899,691	5.4815	95.7990	917,169	5.3524	95.8665
Fruits . .	627,487	3.8231	99.6221	601,350	3.5093	99.3758
Oils and nuts . .	57,097	.3479	99.9700	102,231	.5966	99.9724
Meats . .	4,907	.0299	99.9999	4,717	.0275	99.9999
Fish . . .	20	.0001	100.0000	25	.0001	100.0000
Poultry and eggs . .	0	0	100.0000	0	0	100.0000
Oleomargarine .	0	0	100.0000	0	0	100.0000
Total . .	16,413,087	100.0000	—	17,135,813	100.0000	—

From time to time in the history of man there have been famines. Pharaoh of old directed Joseph to lay up grain during the years of plenty for the famine that was to follow. In modern times the needs of famine-stricken groups are relieved by sending supplies from nations that have plenty in their granaries. China grew enough wheat during the year of their recent famine to feed every Chinese, but many starved because of inadequate transportation facilities. During the Great War and in the years immediately following, the world was called on to feed those in need. The first question was "How much food is needed?" No one knew. Scientific experts had to compile such tables as these on pages 308–311 before the question could be answered.

The following table shows the consumption of foods in the United States, in terms of Caloric value.

Group	For the Six Years, 1911–12 to 1916–17			For 1917–18		
	Absolute Consumption (Million Calories)	Percentage Consumption	Cumulated Per Cent	Absolute Consumption (Million Calories)	Percentage Consumption	Cumulated Per Cent
Grains . . .	45,057,265	34.68	34.68	45,569,323	33.31	33.31
Meats . . .	28,104,069	21.63	56.31	28,122,722	20.55+	53.86
Dairy products .	19,834,010	15.26	71.57	21,010,397	15.36	69.22
Sugars . . .	17,196,595	13.24	84.81	17,939,129	13.11	82.33
Vegetables . .	6,910,026	5.32	90.13	8,999,132	6.58	88.91
Oils and nuts .	6,269,270	4.82	94.95	8,104,157	5.92	94.83
Fruits	2,862,540	2.20	97.15	2,722,604	1.99	96.82
Poultry and eggs	2,620,311	2.02	99.17	2,648,262	1.93	98.75
Oleomargarine .	542,719	.42	99.59	1,170,593	.86−	99.61
Fish	534,509	.41	100.00	533,419	.39	100.00
Total . . .	129,931,314	100.00	—	136,819,738	100.00	—

222. Food Substitutes. — Foods that can be used in place of those that we wish to save are known as *food substitutes*. For example, the substitutes for wheat are corn, oats, rice, barley, white and sweet potatoes; while the following can be used in place of meat: fish and other sea food, milk, cheese, eggs, nuts, legumes, and cereals. Honey, maple sirup, corn sirup, sorghum, and molasses are used in place of sugar; the substitutes for butter and lard are olive oil, corn oil, cotton-seed oil, meat drippings, etc.

In the study of food substitutes a great deal is said about new foods, but there are really no new foods. The use of rye flour, corn meal, and such foods, while new to many people of this generation, were the most common foods with our ancestors as they pioneered and settled the land. We are in reality returning to the simpler forms of food rather than adding new foods. Find out all that you can about the

different kinds of foods that were used by the early settlers in your community.

223. Food Shortage. — Keeping in mind the important fact that all foods have to be grown, it is easy to understand how there may be a food shortage. If the men who are skilled in raising food were all removed from the farms, the storehouses would in a short time be emptied of their supplies,

Courtesy Omaha Chamber of Commerce.

FIGURE 215. — HUGE GRAIN ELEVATOR.

Here wheat and grains are stored before being made into flour and other foods.

and none would be growing to replace them. This would result in a food shortage. With the growth of cities, more food has to be collected and transported for the use of their populations, none of whom are engaged in the production of food, but all of whom require food.

Some appreciation of the magnitude of this phase of our food problem can be gained by learning from your local

dealers where the food used for one day in your home was grown. The problem of giving all the people in our country enough to eat at reasonable prices is one of very great importance and one that you can well afford to study.

224. Increasing the Food Supply. — Whenever an increased demand is made upon the total supply of food in a nation, as was made upon the United States during the years of 1916–1919, attention is directed to two important facts: (1) that we are not using all the available foods, as is noted by a study of food substitutes; and (2) that measures must be employed to increase the total production of food. To show that biological principles are the foundation for all such studies, three examples only will be given.

(*a*) *Fish Production.* — The first food chosen to take the place of meat is fish, because the food value of fish is similar to that of meat. In America there are nearly 70 kinds of edible salt-water fish and more than 30 fresh-water varieties, yet most of us know hardly a dozen. *How many different kinds of fish have you ever eaten?* It is said that every year the fishermen of the Atlantic coast throw away about 10,000,000 pounds of fish that have a higher nutritive value than the famous cod. We are far behind other countries in our use of fish. We use about 18 pounds of fish per person each year, while England uses about 65 pounds and Canada 57 pounds.

We should not only eat more fish but study the conditions under which fish live in order that fish may become more abundant in our fresh-water streams and lakes. Fish freshly caught is a great delicacy. Many of our fresh-water lakes and ponds could be made to supply an abundance of fish food if some intelligent care were taken to supply these ponds with the varieties best adapted to live in them.

Perch, pike, bass, and bullheads have a wide range of adaptation and will thrive in most of our fresh-water ponds. We have not as yet begun to utilize properly the larger streams of our country, which can be made to support a great number

of food-fish if the water in them is reasonably pure. Where the streams are utilized to carry away the sewage of cities and towns, the water becomes so polluted that fish cannot live in it.

(*b*) *Improving the Varieties of Animals and Plants.* — If we compare the domesticated animals and plants in common use 20 years ago with those of to-day we note many improvements. These are due to a large number of experiments that have been carried on largely by the United States Department of Agriculture and the many state experiment stations. Here new varieties are tested and old varieties improved for the benefit of man. The net result of all these experiments has been to increase greatly the usefulness of our many domesticated animals and plants. The up-to-date farmer is thoroughly familiar with the latest discoveries in this field and often pays high prices for improved seed or stock in order that he may obtain a larger yield or better results. By keeping in touch with such improvements, the farmers have greatly increased the total food supply.

(*c*) *War Gardens.* — A " war garden " is a garden in a back lot or other hitherto waste land which is used for increasing food production. In addition to the large number of adults who cultivated war gardens during the years of 1917–1918, there were approximately one million and a half school children enlisted in the United States School Garden Army during the summer of 1918. It is believed that an average of one fifteenth of an acre per pupil is a conservative estimate. This would make a total of one hundred thousand acres. The average production per acre under intensive cultivation at a low estimate ought to be $50, which would give a total of fifty million dollars in value. Experienced truck gardeners expect to make from $1,000 to $1,200 per acre.

In addition to increasing the general food supply, there are two other reasons why the War Garden idea should be per-

petuated. In the first place, the vacant lots of a city or town present a more attractive appearance when under cultivation than when occupied by weeds and rubbish. Secondly, they furnish a splendid opportunity for boys and girls to learn how many of their food plants grow and the meaning of labor.

What other ways can you suggest that will help to increase the general food supply?

225. Public Markets. — These are the places where those who raise garden truck, chickens, and other food products can bring them and the people can buy directly without paying the middleman or the retailer for his services. There is the further advantage that such foods are usually fresh. It is necessary to regulate the public markets in order that the food shall be properly prepared, and correctly weighed or measured. These markets are of great advantage to the poor people in cities, as they can get more good food at less cost than anywhere else. Is the market in your city well regulated? What are the rules governing it?

226. The Preparation of Foods: Cooking. — Some foods, such as milk, fruit, and nuts, may be eaten without being cooked, but most of our food has to undergo this process before it is suitable for eating. As no two kinds of vegetables or meats are best cooked in exactly the same way, attention should be given to the preparation of food for the table. Successful cooking accomplishes three ends. (1) Changes are brought about to make the food more digestible, such as softening or dissolving it. (2) The nutritious parts are carefully saved. (3) The food is made attractive in appearance and taste, "good to eat."

Every woman who wishes to have a happy, healthy family should make a serious study of cooking. Many of the facts about the nutritive elements which foods contain, and the many changes which they undergo in cooking, are found out by chemists who study them in laboratories. It is not necessary for us all to know all these facts, but

a good cook follows the rules and recipes which have been made as a result of scientific laboratory studies.

Bread. — To illustrate the principles involved in cooking, let us see what it means to produce a loaf of wholesome bread. Flour contains much starch, some sugar, some mineral substances known as phosphates, a large quantity of gluten (a protein), and some bacteria (tiny plants, see Chapter

FIGURE 216. — RAISING WHEAT FOR FLOUR.

XXIV) which may or may not be of value in making bread. When water is added to the flour, it becomes tough and sticky, this being a characteristic of gluten, and the most important one, so far as the making of bread is concerned. A small bit of yeast (a small plant, see Chapter XXXIII) is added to the water used in making bread, and the dough is placed where it will be neither too hot nor too cold (70°–80° F.).

The yeast begins to grow rapidly, feeding on the proteins of the flour, and as the yeast grows, it acts on the sugar.

An enzyme called *zymase* (zīm′ās), secreted by the yeast plant, breaks the sugar up into carbon dioxide, alcohol, and a small quantity of *glycerin*. The gas tries to escape, but is held in by the sticky dough. If the yeast plant is well distributed, the gas collects in many small bubbles, and the loaf is fine-grained. The alcohol keeps other plants from growing there, and also helps to soften the gluten.

When the loaf is put into the oven, the heat kills the yeast plant, drives off the carbon dioxide, and causes the alcohol to evaporate. The heat changes the gluten into a substance more easily digested and of a more pleasant taste. In " salt rising " bread, bacteria from the air, instead of yeast cells, form the gas which makes the bread light. When a batch of bread " sours," it is usually because harmful bacteria get into the dough and grow more rapidly than the yeast plants. Sometimes other kinds of yeasts than the helpful ones employed in bread-making accidentally get into the batch of bread and it spoils as a result.

During the war we used substitutes in our wheat flour with the result that many good cooks were not able to make as good bread as usual. This was not the fault of the cooks, but was due to the following facts. Although corn, barley, and wheat flour contain nearly equal amounts of similar proteins, the proteins of corn, barley, and rye do not react the same to water and the acids produced during fermentation. The dough made from these substitute flours does not hold together and is not so distensible as that made from wheat flour. These unfavorable conditions of the dough can be improved by adding a small amount of what is known as the " proteins of serum," a special preparation that is in the form of a dry powder.

227. Adulteration of Foods. — Foods are adulterated either by subtracting some of the nutritious parts and substituting less valuable parts, or by adding materials which cannot act as a food.

The food formerly subject to the most adulteration was milk. This adulteration was accomplished by adding water to make the milk go farther when being measured out, and adding *formalin* (fôr′mȧ-lĭn) to make it keep sweet.

For a time many of the cereals were adulterated with sawdust, peanut shucks, or bran. Many of the special foods put up in packages used to be adulterated, and it would require a long description to enumerate all that have been found unsatisfactory for food by the Department of Agriculture.

Pure Food Laws. — The Food and Drugs Act passed by the United States Congress on June 30, 1906, requires of manufacturers of foods and drugs that a definite statement be made as to their composition. A number of regulations and rules have been issued from time to time. The last was issued June 15, 1917, and related to the marking of the quantity of food in packages. Here we find that when food is in package form, it must be plainly marked in terms of weight, measure, or numerical count on the outside of the package. The quantity of the contents so marked shall be the amount of food in the package.

This Act established high standards for many of the common and necessary foods of man. Before its adoption there was no standard for the manufacturers to go by. One of the reasons why it has been so valuable is because it includes so many different products. Food standards have been established for the following: meats, meat extracts, milk, cream, butter, cheese, ice cream, grains, meals, flour, fruits, vegetables, flavoring extracts, of which there are twenty-four, tea, coffee, cocoa, vinegar, and salt.

The wide range of patent medicines and drugs comes under the influence of this act and we can now read their composition on the label. This is a great protection against misbranding and cheating.

228. Impurities in Water and Milk. — The utmost care is taken to protect the water supplies of our cities. The

sources are watched and filthy streams are not permitted to drain into the reservoirs. If this were not done the water might become contaminated with various disease germs, notably those of typhoid. If there is any doubt about the purity of your drinking water, it should be boiled for thirty minutes and cooled before being used.

The same food substances in milk that render it one of the best foods for man make it equally valuable to the large number of domestic animals that man uses as his sources of meat. On the other hand, there are certain plants, the bacteria, that find milk one of the best of foods for their growth. Some of these bacteria, such as the typhoid fever and diphtheria germs, are very dangerous to our health when they chance to be introduced into milk. This is the reason that such stringent laws have been passed regulating the care of milk that is sold. But these laws which are made to give us a high grade of clean milk do not follow the milk into the home, where it is often left exposed to contamination. The same care that is taken in keeping the milk clean before it is bottled should be exercised after the bottle reaches our homes.

229. Stimulants and Narcotics. Drug Habits. — There are several substances that are taken in with the food that are not regarded as foods in the proper sense. Tea and coffee are common stimulants. If correctly made, they are not harmful to adults but because of the stimulation are undesirable for children. These common drinks are called stimulants because they increase the general activity of the body, but they neither build tissue nor release energy, so cannot be regarded as foods. Cocoa contains some nutritious material.

Before studying this subject further we must understand the meaning of the terms *poison*, *anesthetic* (ăn-ĕs-thĕt'ĭk), and *narcotic*. A poison is a substance which when taken into the body tends to cause death. Aconite, opium, carbolic acid,

and mercury are all poisons, and when taken in sufficient quantities cause death.

An anesthetic is a substance like ether or chloroform, which when breathed into the lungs causes a temporary loss of sensation. Unless anesthetics are administered properly, they may cause death.

A narcotic is a substance which causes dullness or stupor, and even a temporary relief from pain.

The narcotics often have a quieting effect which is sometimes associated with a pleasurable feeling. The common narcotics are opium, chloroform, cocain, laudanum, chloral hydrate, alcohol, and various patent preparations.

Many preparations are taken by persons ignorant of the fact that they generally contain these harmful drugs. It should be sufficient to know that no reputable doctor will ever give any of these preparations except in a mild form, and in case of extreme pain. No person except a trained physician has a right to prescribe drugs; and he only after a knowledge of the patient's symptoms. Many of these preparations affect the heart and blood, and none of them has any beneficial effect.

In most cases these drugs are taken at first to narcotize or deaden the pain in the nerves. Then their use continues, until in a short time a habit is developed. The drug habit is more difficult to stop than the alcoholic. None of these narcotics has a remedial effect on the cause of the pain. They are being used very sparingly nowadays by the best physicians because of the lurking danger of the drug habit.

230. Alcohol.[1] — To understand why alcohol is classed as a narcotic, we must learn about a substance called *lipoid*

[1] Those who are interested in making a more critical study of the relation of alcohol to the various forms of activity of man and animal should consult the two volumes, Physiological Aspects of the Liquor Problem, edited by John S. Billings, Houghton Mifflin Co., Boston; also, The Action of Alcohol on Man, by Ernest H. Starling, Longmans Green & Co., 1924; The Defenses of the Body against Alcohol, Daniel — Popular Science Monthly, page 159, 1924.

(lĭp′oid: Greek, *lipos*, fat; *eikos*, like). Lipoid is very like fat except that it contains nitrogen and phosphorus, which fats do not. It also mixes with water, and it can make certain bodies soluble which are otherwise not soluble. While there is no part of any cell in the body that is without this material, perhaps the largest accumulation of lipoid is that in the nervous system, especially the brain. Each nerve fiber that conveys messages into or out of the brain is insulated with lipoid and thus the stimuli are prevented from scattering.

A few years ago scientists discovered that any substance that dissolves lipoid, or is dissolved in lipoid, is an anesthetic. Chloroform, ether, and all the agents used in modern surgery to produce unconsciousness are dissolvers of lipoid. Besides acting as anesthetics these substances act as poisons to every cell in the body as well. The brain, because of its high percentage of lipoid, is more sensitive than other organs to the action of chloroform.

The fact that lipoid is soluble in alcohol, makes alcohol rank as a narcotic poison.

Alcohol Shortens Life. — In 1909 forty-three of the leading insurance companies in the United States and Canada agreed to make an impartial study of all their records for the past twenty-five years. This involved an examination of 2,000,000 insured lives. The insured were divided into many classes, such as railroading, mining, manufacturing, and users of alcoholic liquors. The two following statements are made by Arthur Hunter, the chairman of the committee, in a study covering a period of three and one half years.

"*Habits as to Alcoholic Beverages.* — Nothing has been more conclusively proved than that a steady, free use of alcoholic beverages, or occasional excesses, are detrimental to the individual. In my judgment, it has also been proved beyond peradventure of doubt that total abstinence from alcohol is of value to humanity; it is certain that abstainers live longer than persons who use alcoholic beverages. The low mortality among abstainers may not be due solely to abstinence

from alcohol, but to abstinence from tobacco, and to a careful regard for one's physical well-being.

"Among the men who admitted that they had taken alcohol occasionally to excess in the past, but whose habits were considered satisfactory when they were insured, there were 289 deaths, while there would have been only 190 deaths had this group been made up of insured lives in general. The extra mortality was, therefore, over 50 per cent, which was equivalent to a reduction of over four years in the average life of these men. If this meant that four years would be cut off the end of the average normal lifetime of each man, there are many who would consider that 'the game was worth the candle'; but it means that in each year a number of men will die at an earlier age than they should. For example, at age 35, the expectation of life is 32 years: in the first year after that age, instead of, say, 9 persons dying, there would probably be 12 deaths; that is, three men would each lose 32 years of life; in the next year probably four men would each lose 31 years of life, etc. As a matter of fact, many immoderate drinkers would live longer than 32 years, but not nearly so many as would live if they had been moderate drinkers, and far fewer than if they had been total abstainers from alcohol."

Structural Changes Due to Alcohol. — Definite changes are found in the protoplasm of nerve cells after the use of alcohol. These consist in a shrinking of the nucleus, the loss of the spindle-shaped (Nissl) bodies (Figure 247), the swelling of the cell, and the presence of vacuoles in the cytoplasm. It is also probable that some of the nerve cells are actually destroyed. These physical changes explain why the results are so great and why complete recovery of mental efficiency in the drunkard is so doubtful. The modern point of view and the one which is becoming firmly established in the treatment of drunkards by physicians is that alcoholism is a disease.

Anything which can destroy all the higher and finer emotions, take away ambition, destroy shame, modesty, pride in personal appearance, render one especially liable to common diseases, or lead unerringly to insanity is to be avoided.

231. Tobacco. — "Training starts to-morrow, no more smoking," is part of the athletic coach's orders at the begin-

ning of each season. He knows that the boy who smokes cannot reach his highest efficiency or be relied upon at critical times in the contest. He would rather have boys who do not smoke, because they are stronger, larger, and steadier than those who smoke. The cigarette habit has spread until it threatens the health of thousands of boys of America today. How is it known that their health is not good? The charts on " smoker's heart " prove this point.

How the Smoker's Heart Is Affected. — The following illustrations on the rate of the heart beat and the strength of the pulse, by W. A. McKeever, for thirteen years professor of Philosophy in Kansas University, show what really happens when we smoke. There is much in these illustrations to warrant the conclusion that the heart of the habitual cigarette smoker is weak and feeble, except for the few minutes during which he is indulging the habit, and that the pulsations at this time are unduly excited. Figure 217 shows three records of a young man nineteen years old who began smoking cigarettes at the age of fifteen and who inhaled the fumes. The three records were taken without removing or readjusting the instrument, as follows: No. I, immediately before smoking, No. II, during the indulgence of the habit, and No. III, fifteen minutes later, after the effect of the narcotic had become apparent. Now, by reference to Figure 218, No. III, we may observe how this young man's heart should record itself, for the latter is the tracing of the heart pulsations of a normal young man of the same age and temperament. Nos. IV to VI

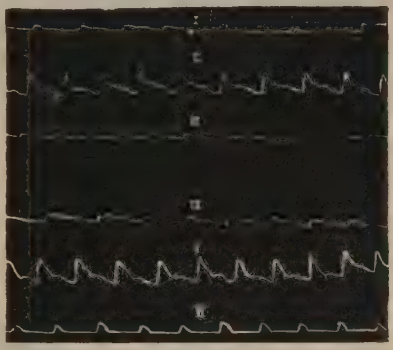


FIGURE 217.

(Figure 217) are representative of another inhaler twenty years old, who began the practice at thirteen. He now uses a strong pipe.

In Figure 218, Nos. I and II, taken respectively before and after smoking, are tracings of a sensitive youth of eighteen who has been smoking only two years. Observe the skip of his heart beat at *x* and the corresponding partial skip under the stimulus of smoking in No. II. No. III (Figure 218), as mentioned above, is a tracing of a strong healthy heart of a young man of somewhat excitable temperament. No. IV represents the phlegmatic temperament; that is, a person who is not excitable. No. V is the heart tracing of a strong and healthy young woman.

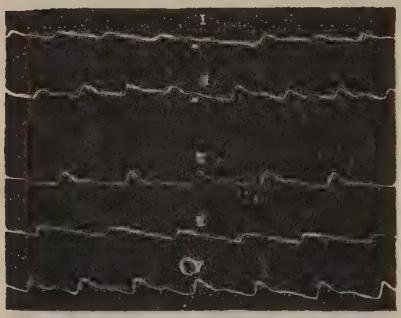


FIGURE 218.

In Figure 219, Nos. I and II are the pulse records of a man of splendid physique, thirty-six years old and weighing 230 pounds. No. I was taken before and No. II after smoking a cigar. He does not inhale. His pulse responded readily to the stimulus, but as the first tracing indicates he does not seem to suffer from any heart prostrations between indulgences. No. III is the record of a person whose vitality is temporarily low from nervous fatigue. No. IV is the

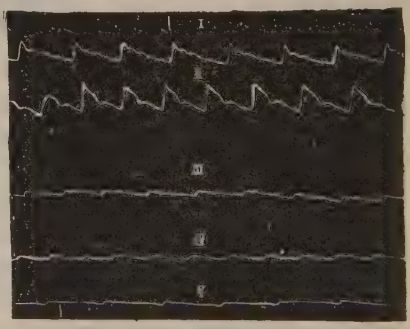


FIGURE 219.

record of a young woman who was on the verge of nervous prostration. No. V is representative of a heart weakened by long indulgence in the smoking habit. The young man in question began early and continued the practice till his physician convinced him of the extreme danger threatening his life. The pulse wave is nearly normal in length, but is entirely too weak. Under such conditions of heart action a man is capable of little courage or aggressiveness.

Says Mr. McKeever:

"From the foregoing evidence we are led to the conclusion, that in the case of boys and youths, cigarette smoking is very deleterious to the physical and mental well-being. Moreover, my investigations indicate that it makes very little difference in the effects whether the victim uses pipe or cigarettes, provided he inhales the fumes; and with few exceptions the young smokers are inhalers. The ordinary case exhibits about the following type of conduct: (1) While the craving is at its height the victim manifests much uneasiness and often much excitation. (2) During the indulgence the cheek is alternately flushed and blanched, the respiration considerably increased, and the hands tremble. (3) About twenty minutes after smoking the muscles become relaxed, the respiration slow and shallow, the skin on the face dry and sallow, and there is an apparent feeling of unconcern about everything."

Smoking and Scholarship. — Several thousand boys have been studied and classified according to age and whether they were smokers or non-smokers. In all cases the non-smokers had a higher average grade of scholarship. The experience of city superintendents and principals is that they can usually tell a cigarette boy by his general attitude, poor scholarship, and disregard of personal appearance.

When cigarettes are burned, three distinct poisons are produced, which cause serious effects on the boys who use tobacco in this form. These poisons are absorbed in small quantities by the mucous membrane which lines the nasal passages and in larger quantities when the smoke is inhaled into the lungs.

A simple way to prove that cigarette smoke contains a

poison is by blowing the smoke through a glass tube into an aquarium containing goldfish. Only a small amount of smoke will kill the fish.

While we all can gradually adapt ourselves to small amounts of poison, poisons are never beneficial unless prescribed by a physician to try to remedy some bodily defect. The poisons which arise from the burning of a cigarette are never prescribed even as medicines, and have never been found in any way beneficial to the human body.

232. Quacks and Patent Medicines. — The term *quack* is applied to a person who pretends to skill or knowledge which he does not possess. Technically, a *patent medicine* is a medicine whose composition is a matter of public record, and for which letters-patent have been granted which give the patentee the exclusive right to the manufacture and sale of this product for seventeen years. Colloquially, however, a " patent medicine " is a remedy, usually secret in composition, to which a fancy name has been given and that name trade-marked. Such a trade-mark gives to the owner a perpetual monopoly on the name, while it imposes no restrictions on the composition of the product that goes under that name. Most so-called patent medicines are of the latter type and are really not patented at all. Many millions of dollars are spent annually in advertising special " cures " and mechanical contrivances guaranteed to cure diseases for which they can do nothing, or even to cure such diseases as cancer, tuberculosis, epilepsy, etc.

Nostrums and Cure-alls. — Many people who do not understand the causes of disease are reluctant to consult a well-trained physician, but read and believe the carefully worded advertisement of some quack doctor or of some patent medicine. The untrained sufferer cannot interpret the meaning of his distress and is incompetent to select the proper medicine. As real medicine is given for specific symptoms associated with a specific disease, it is apparent that a patent

medicine advertised to cure from six to forty diseases is worthless. Furthermore, real medicine is given to relieve a certain set of symptoms at a given stage of the disease, and is frequently changed. This is, of course, impossible when using a patent medicine. If every one would consult regular physicians, and cease patronizing the quacks and patent medicines, one of the sources of much sickness and suffering would be removed.

Our government through its enforcement of the Food and Drugs Act is doing a great deal to protect those who do not understand about disease and its cure. This Act is too limited and should be revised and its scope broadened; for we find since its passage that there has been an increase in the number of remedies sold as " cures " for epilepsy. The main drug in these fakes is bromide of potassium, which is harmful to the patient, especially in the large doses recommended. While this drug has the power to suppress temporarily the epileptic attack, it leaves the sufferer in a worse condition.

Deafness Cures. — The number of " deafness cures " is legion. The middle and inner ear, where all diseases of the ear are located, is separated from the brain by a thin partition of bone and it is extremely dangerous to permit quacks to tamper with such a delicate organ as the ear. At the present stage of our scientific information, very little can be done to cure deafness. By writing to the American Medical Association, Chicago, Ill., you can secure much information about alleged cures for deafness as well as about patent medicines and mechanical contrivances.

Obesity Cures. — Woman's fashions during the past few years gave a wonderful stimulus to the exploiters of " obesity cures." The desire to be slender — often far beyond what is compatible with good health — caused thousands of women to waste their money on so-called reduction treatments that were either dangerous or worthless or both.

Thyroid extract was the basis of many of the "fat reducers" first put on the market, and this drug is still somewhat in use. We are all beginning to realize that this is a dangerous drug, so that other things have had to be substituted. A very common sea-algæ, the kelp, has been used in many of the fat-reducing preparations. It is difficult to find out why this plant is so popular because in some localities farmers have used it as food for their hogs in the belief that it makes them fat. Overeating and too little exercise are the chief causes of obesity. Remove the causes and stop buying fakes.

Pimples. — Between the ages of twelve and eighteen usually, nearly all children have pimples, especially on the face. There is no remedy that will prevent them. The same can be said about the tendency of those of light complexion to sunburn or freckle, only here there is no age limit. Catering to the ignorance and pride of girls especially, fakirs advertise numerous cosmetics and lotions for the skin and hair. Many of these have been analyzed by the chemists of the government and found to consist of borax, starch, epsom salts, soap, and other common substances which cost from one to three cents a bottle and for which the user pays fifty cents a bottle.

Testimonials. — Testimonial letters stating that the writer has been greatly benefited by a given patented preparation or mechanical contrivance are abundantly used by all fakirs. An official of the United States Post Office once wrote: "Speaking generally it may be said that in all my experience in this office never has a medical concern, no matter how fraudulent its methods or worthless its treatment, been unable to produce an almost unlimited number of these so-called testimonial letters." An investigation by the American Medical Association has shown that some of these letters are purchased, some written in the office of the "patent medicine" concern, and some actually written in good faith.

Those who write the letters in good faith are relatively few in number and nearly always ignorant and unable to judge accurately of the cause of their trouble. Many of them after writing of the benefits are found to be just as deaf or epileptic as before. In the case of consumptives who write of being helped, it is only necessary to wait a few months and the death certificates are available as silent testimonial to the fake.

As the United States Government has been more and more successful in prosecuting the ordinary frauds, the propagators of fakes have become more skillful, especially in the false-scientific manner of advertising.

The following is from "*The Nostrum and the Public Health*," an article published in the Journal of the American Medical Association, May 24, 1919, written by Arthur J. Cramp, M.D.:

"The physician, of course, is opposed to the average 'patent medicine' because it is exploited in such a way as to cause the public to magnify its trivial ailments, to drug itself unnecessarily and in cases in which something serious is the matter to lose vitally valuable time in seeking medical aid. . . .

"Unfortunately, the home remedies of to-day are, generally speaking, 'patent medicines'; and the methods of promoting the sale of patent medicines make those products a menace to the public health. This not altogether for what the remedies themselves contain, although in many instances that is distinctly bad, but because of the way such products are exploited. . . . So to advertise as to make well men think they are sick and sick men think they are very sick, for the sole and only purpose of causing them to purchase drugs to pour down their throats, is more than an economic offense; it is a crime against the public health. Yet this is the principle on which the average 'patent medicine' of to-day is sold."

Students of even such an elementary course of biology as this, possess the needed information to enable them to tell the difference between fakes and real remedies. This is one of the important results that you should obtain from this study. Learn to seek for the real cause of disease by consulting the family physician, and pay no attention to testimonials for fake cures.

Alcohol in Patent Medicine. — Many patent medicines contain a considerable amount of alcohol. Since the passage of the national Food and Drugs Act, which went into effect January, 1907, the presence and quantity of alcohol in " patent medicines " has to be declared on the label. This alone tended to reduce the amount of alcohol in many of them but there still remained a large number of preparations whose most active and powerful drug was alcohol. Some of these were so slightly medicated that the United States Government would not permit them to be sold except under a liquor license. Since the advent of prohibition, of course, these can be sold only under the strict regulations governing the prescribing of alcohol.

Some patent preparations contain also cocain or opium, and should not be taken for this reason.

Alcohol and Disease. — It is unnecessary to make an elaborate series of quotations from eminent men to prove that alcohol is not useful and necessary as a medicine in the cure of disease. There is no evidence that alcohol has any effect on the destructive course of a disease, or any beneficial effect upon the person suffering from disease. This last phase of the problem has been under critical study long enough to show that the earlier claims of the helpfulness of alcohol in disease are not supported by the facts. The reverse is true. Alcohol is known to decrease the power of the body to withstand disease and does not assist in destroying the poisons which arise in the case of bacterial diseases. It should never be used unless definitely prescribed by a physician.

OUTLINE

- Common nutrients
  - Primary foods
  - Secondary foods
- Food classification
  - Proteins
  - Carbohydrates
  - Fats
  - Mineral matter
  - Vitamins
  - Economy in purchasing
- Milk
  - Universal food
  - Of various animals
  - Composition of
- Vegetables and fruit
  - Variety
    - For young children
    - For older children
- Meaning of Calorie
  - Unit of heat
    - Greater Calorie
    - Lesser calorie
  - Use in measuring diet
- Vitamins
  - Different kinds
    - A, B, and C.
  - Uses
    - Aid digestion
    - Stimulate cells
    - Manufacture chemicals
  - Table of vitamins
- Food groups
  - Tables
    - Proteins
    - Fats
    - Carbohydrates
    - Caloric value
  - Substitutes
- Food supply
  - Shortage
    - How prevented
  - Increase
    - Fish production
    - Improving
      - Animals
      - Plants
        - War gardens
  - Public markets
- Preparation of foods
  - Cooking
    - Bread
      - Substitutes
  - Adulteration
    - Pure food laws
- Impurities
  - In water
  - In milk
- Stimulants and narcotics
  - Anesthetic
    - Ether
    - Chloroform
  - Poison
    - Carbolic acid
    - Mercury
  - Narcotic
    - Alcohol
      - Shortens life
      - Changes structure
    - Tobacco
      - Affects heart
      - Hurts scholarship
- Quacks and patent medicines
  - Nostrums
    - Deafness
    - Obesity
    - Pimples
  - Testimonials
  - Alcoholic content

SUMMARY

The energy which enables the human body to move, to grow, and to repair tissue comes from the food eaten. These foods fall into three classes, proteins, fats, and carbohydrates. Water, vitamins, and minerals are necessary for health.

All of these foods in the last analysis depend on the activity of green plants as they manufacture food out of the raw or unusable compounds, water and carbon dioxide. These foods are digested before they can be absorbed into the blood. The blood carries the absorbed food to all the cells of the body.

The fact that man cannot live without food has made it imperative that he be protected from food adulterations which are harmful to him. It is a very rare patented preparation that has a greater food value than the regular foods of our diet.

The use of stimulants is wholly unnecessary for young people, and never beneficial, as they do not contain food that is of any importance.

Cocoa is an exception because it is a food as well as a stimulant. Alcohol is a dangerous stimulant, and when taken in large amounts is a definite narcotic.

There is no experimental evidence that tobacco is helpful to growing boys and girls. All of the evidence indicates just the reverse. No person under twenty years of age should use it.

QUESTIONS

Define foods. How many kinds are there? Describe them. How do they form in nature? Can man make food out of the raw compounds? What living things can? What is digestion? Absorption? What are stimulants? What are narcotics? What is the experimental evidence against the use of tobacco by boys?

CHAPTER XX

DIGESTION AND ABSORPTION

Man is a carnivorous production,
And must have meals, at least one meal a day;
He cannot live, like woodcocks, upon suction,
But, like the shark and tiger, must have prey;
Although his anatomical construction
Bears vegetables, in a grumbling way,
Your laboring people think beyond all question,
Beef, veal, and mutton better for digestion.

— Byron

233. The Digestive Organs. — Man's digestive organs consist of the same parts as those already studied in the frog. But each region of his digestive organs is more complete and the biological principle, the division of labor, reaches its highest development in man. The parts of the *alimentary canal* in man are: the mouth, containing the teeth, tongue, and glands; the throat or pharynx; the esophagus; the stomach; the small and the large intestine. These several parts form a continuous tube, and each does a particular work in digestion (Figure 220).

The Mouth. — The mouth is lined with a soft membrane, kept moist by the saliva secreted by three pairs of glands, and poured into the mouth in sufficient quantities to moisten the dry food and thus assist in swallowing. The tongue is a muscular organ and bears on its upper surface many small fleshy projections called *papillæ* (pà-pĭl'lē: Latin *papilla*, bud), some of which are fairly large and are arranged on the back of the tongue in the form of a V (Figure 221).

Our power to taste sweet, sour, bitter, and salt, which are the four fundamental tastes in man, is due mainly to certain nerve cells located on the larger papillæ. The food stimuli

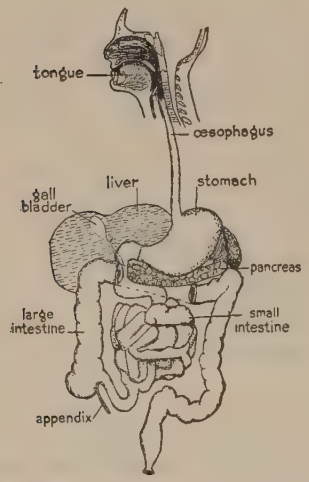


FIGURE 220. — ALIMENTARY CANAL OF MAN, WITH ITS TWO CHIEF DIGESTIVE GLANDS, THE LIVER AND PANCREAS, CONNECTED WITH THE SMALL INTESTINE.

The spleen is not a digestive gland. The salivary glands connect with the mouth and are not shown.

FIGURE 221. — TONGUE OF MAN, SHOWING TWO OF THE THREE KINDS OF PAPILLÆ.

The circumvallate papillæ are at base of tongue and about five or six in number; the fungiform papillæ are numerous, round, mushroom-like projections scattered over the surface of the tongue. The third type of papillæ, the filiform, are the most numerous and like coarse hairs. You can recognize these papillæ on your own tongue.

received by the special sensory cells of the papillæ are carried to the brain by the taste nerves. In the brain the food stimulus is interpreted as sweet, sour, or bitter (Figure 222).

LABORATORY STUDY

Blindfold in turn several members of the class and have each hold his nose while a small amount of some highly flavored food is placed on the tongue. Such common foods as maple sirup, vanilla extract, mar-

malade, jams, etc., are admirable for this test. Make a record of each test. This experiment will prove that we do not taste flavors. Remove the hand from the nose and again taste the same substances. This time there will be no difficulty in telling the name of the substance because it has been smelled as well as tasted.

The roof of the mouth is called the *palate*. The front part contains supporting plates of bone and is therefore called the hard palate. The back part (the soft palate) is a thin sheet of muscle covered by the mucous (mū′kŭs) lining of the mouth. The soft palate separates the mouth from the nasal cavity. Beyond the soft palate is the throat cavity, called the *pharynx*. This is a funnel-shaped cavity, having two openings at its lower end, the front one being the opening into the windpipe which leads to the lungs, and the rear one, the opening into the esophagus. In the upper part of the pharynx, on each side, is the opening of a *Eustachian* (ū-stā′kĭ-an) tube which passes to the middle ear.

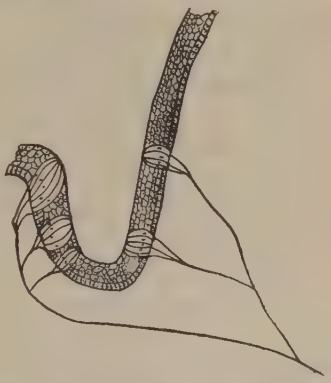


FIGURE 222. — DIAGRAM OF TASTE CELLS IN THE TONGUE.

The taste cells are much longer than the surrounding cells. The nerve which carries taste stimuli to the brain ends among these long cells.

The Esophagus.— The esophagus is a nearly straight tube connecting the mouth with the stomach. It passes through the *diaphragm* (Figure 186), enlarges, and becomes the stomach. As soon as one swallows, control of the food is lost, and further action becomes involuntary. Two sets of muscles, one extending lengthwise, the other around the esophagus, act together in forcing the food or water into the stomach. This explains why we can drink from a brook when the head is much lower than the stomach.

The Stomach. — In man the stomach is the largest section of the digestive tube, and it has a capacity of about three pints. It is usually described as pear-shaped, although there is much variation in its form (Figures 223 and 224). At the point where the esophagus joins the stomach there is a muscular ring (*cardiac* valve, kär′dĭ-ăk) which ordinarily prevents the food from passing again into the esophagus. In vomiting, this valve becomes relaxed. The opening at the larger and lower end of the stomach is guarded by a similar valve (*pyloric*, pĭ-lŏr′ĭk), which serves to retain the food in the stomach until certain digestive changes have taken place.

FIGURE 223. — PEAR-SHAPED HUMAN STOMACH.

The intestine has two parts, a small, much coiled tube about an inch in diameter and about twenty feet long called the *small intestine*, and a large section about five feet long and four inches in diameter, bent in a rough ∩ shape and called the *large intestine*. At the junction between these two regions projects a short sac, the *vermiform appendix* (vēr′mĭ-fôrm ap-pĕn′dĭks). The disease called *appendicitis* (ăppĕnd-ĭ-sī′tĭs) affects this organ. The large intestine ends in a special region called the *rectum*. The opening of the rectum to the outside is the *anus* (ā′nŭs).

FIGURE 224. — X-RAY PHOTOGRAPH OF HUMAN STOMACH.

This is a shape familiar to physicians and is just as normal as the shape shown in Figure 223.

The esophagus, stomach, and intestine are each lined with a membrane that is similar to that found in the mouth cavity. This membrane is called the mucous membrane. In the esophagus, the mucous membrane is smooth and moist, thus furnishing an easy passage for the food; in the stomach this

membrane is in folds except when the stomach is full of food; and in the intestine, it has a velvet appearance due to projections called *villi* (Figure 225). The numerous glands of the stomach and intestine are located in the mucous membrane.

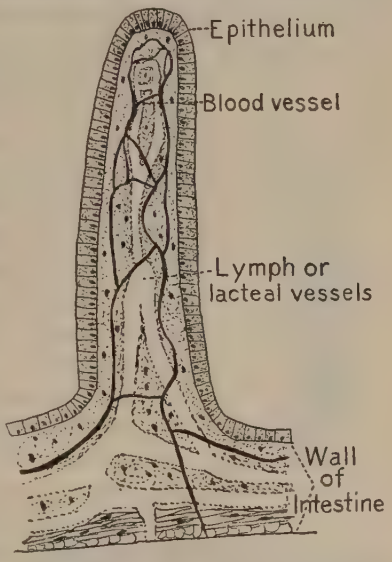


FIGURE 225. — DIAGRAM OF A VILLUS FROM THE INNER WALL OF THE INTESTINE.

Glands. — A gland is a group of special cells which secrete a fluid. The glands which produce the digestive fluids are (1) the three pairs of *salivary* (săl'ĭ-vă-ry) glands, located below the ear, and beneath the tongue and lower jaw; (2) the numerous *gastric* (găs'trĭk) glands found in the lining of the stomach, possibly 5,000,000 in number (Figure 226); (3) the *pancreas;* (4) the *liver,* the largest gland in the body; and (5) numerous *intestinal glands* in the small intestine.

STUDENT REPORT

Fill out the following table and describe the digestive system of the animals studied in Part I. This will help you to understand better the parts of the digestive system of man and the work that each part does.

	ONE CELL	MANY CELLS	NO DIGESTIVE TUBE	DIGESTIVE TUBE	NO WELL-DEFINED DIGESTIVE GLANDS	WHICH ONES REQUIRE FOOD?
Paramecium						
Frog . . .						
Man . . .						
etc. . . .						

234. Digestion. — Digestion begins in the mouth. The teeth break up the food and mix it with the fluid of the mouth, the *saliva* which contains the enzyme,[1] *ptyalin*. During this process, sugars and starches are changed into soluble sugars. The fluids of the mouth are usually slightly *alkaline* (ăl'kȧ-līn or līn, a chemical term, the opposite to sour or acid), but as soon as the food passes into the stomach it enters an acid (sour) medium, and the digestive action of the saliva is destroyed in a short time by the stomach fluid. For this reason, the sugar and starch undergo no further digestive changes until they reach the intestine.

FIGURE 226. — HUMAN GASTRIC GLAND.

The lining cells of the inner wall of the stomach project into the tissues of the stomach as minute pockets. The cells shaded in this drawing are the ones that are at the end of the pocket and are the ones that secrete the gastric juice.

Into this acid medium of the stomach, the gastric glands (Figure 226) pour out the gastric juice (a digestive fluid), and the enzyme pepsin in this juice acts on the proteins so that they can later pass through the walls of the intestine. In the stomach the heat of the body dissolves some of the fats into oils, but many of the fats used as food remain solid at body temperature and are unchanged in the stomach.

After one or two hours the food passes into the intestine and undergoes further changes in another alkaline medium. Here the pancreatic juice, which is made in the pancreas, comes into contact with the digested and partly digested food, causing three different changes. One is to complete the change of proteins into simpler products; a second is to finish con-

[1] The enzymes (en'zīm: Greek *enzymos*, ferment) or ferments, are the chemical bodies which digest the food. All plants and animals digest their food by means of enzymes.

verting starches into sugar; the third is to assist the bile (the digestive juice made in the liver) to digest the fats. The digestion of the food is practically completed in these three regions of the digestive tube, although digestion continues to some extent after the food is passed into the large intestine.

There are three different enzymes in the pancreatic juice (trypsin, amylopsin, and steapsin), none in the bile, and one in the saliva.

Inorganic foods, such as water, oxygen, and salts, man takes into his body, making them part of his living protoplasm, or using them in oxidation. There is a large amount of water in man, enough to make up nearly two thirds the total weight of his body. All of his food contains water.

Oxygen is breathed in from the air, and the various salts, such as common salt, *sodium chloride* (sō′dĭ-ŭm klō′rīd, or rīd), *calcium* (kăl′sĭ-ŭm), *magnesium* (măg-nē′zhĭ-ŭm, or -shĭ-), *potassium* (pō-tăs′sĭ-ŭm), and *phosphorus* (fŏs′fŏr-ŭs) are taken in with our food. They are useful to the body. A small amount of iron is also contained in food and water and becomes a part of the red blood cells.

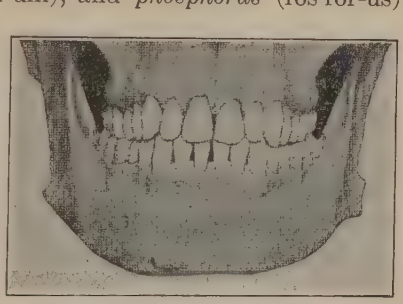


FIGURE 227. — PERMANENT TEETH.

235. The Teeth. — In the mouth cavity just back of the lips are the teeth. These are especially adapted to the different kinds of work each has to do. In adults there are thirty-two, sixteen in each jaw, belonging to four classes according to shape. In front are the eight *incisors* (in-sī′zers) with sharp cutting edges; next the four sharp-pointed *canines* (kā′nīns), and back of the canines the eight *pre-molars* (prē-mō′lers),

shaped for tearing and crushing, while the remainder of the teeth, twelve in number, are the flat-topped *molars* which do most of the grinding of the food.

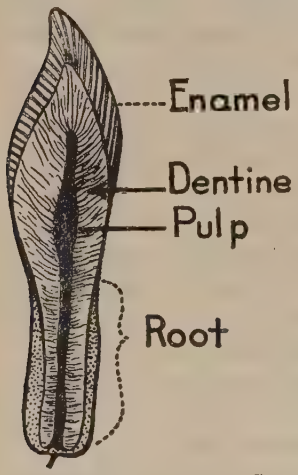


FIGURE 228. — VERTICAL SECTION OF TOOTH.

Care of the Teeth. — We all know that the teeth are hard. That, however, does not prevent them from becoming broken by carelessness or accident, or from decaying because of neglect. When the teeth are not cleaned, a substance called *tartar* forms on them, which prevents the bacteria from being rubbed off and sometimes pushes the gums away from the teeth.

In 1923 bacteria were isolated that cause decay in teeth. These bacteria manufacture their own acid, which softens the enamel of the tooth, causing it to turn dark in color; then these same bacteria penetrate deeper into the parts of the tooth, where they cause a more rapid and extensive destruction. The action of bacteria is hastened by the formation of acids from the particles of food which remain in the mouth after eating. The activity of these bacteria results in toothache, a foul breath, and the imperfect chewing of the food. The teeth should be brushed after each meal to remove particles of food, particularly sugar, which ferments easily. At least once a

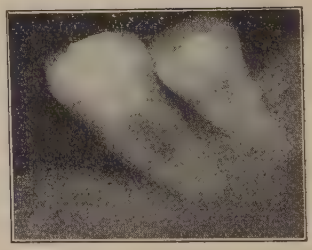


FIGURE 229. — X-RAY OF TWO TEETH.

Note how firmly the bone fits around the roots. These teeth are in good condition. The white blotches are the places where the teeth have been filled. This is the new way of examining teeth.

year there should be a visit to the dentist, who will remove those portions of teeth that are decayed and fill cavities, thus preventing further decay.

Poor teeth cannot be made good by brushing, but they can be greatly helped by daily care, if aided by the dentist. The teeth of children often come in on the outer or inner side of the jaw instead of on the middle. This results in an irregular row of teeth. Such teeth do not meet the opposite teeth as they should (Figure 230). Dentists know how to straighten such teeth, and produce better results if they can begin their corrective treatment before the teeth are fully grown. This is very important, not only for one's looks, but especially for one's health, as without such treatment proper mastication is often impossible.

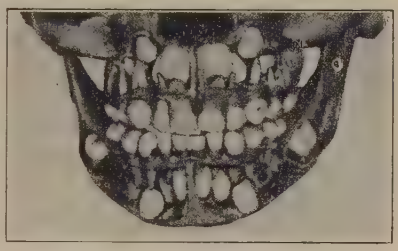


FIGURE 230. — MILK TEETH.
Age 3½ to 4 years. Notice the permanent teeth deeper in the jaws.

LABORATORY WORK

Experiment on Starch Digestion. — Place some starch paste in a test tube. Add saliva and mix. Keep warm, and after twenty minutes test with Fehling's solution (page 42). The reaction will show that the starch has been turned into grape sugar. The starch has been digested by the digestive *ferment* or *enzyme* in the saliva called *ptyalin*.

236. Importance of Mastication. — It is hard to overestimate the importance of chewing the food. Probably more bodily ailments come from hasty eating than from any other cause. Some years ago Dr. Fletcher started a nation-wide campaign for more thorough chewing, and the word "fletcherize" was coined to indicate complete mastication.

All food should be chewed till it slips from the mouth without effort.

Only by chewing can we mix *saliva* with our food. This secretion of the salivary glands keeps the mouth moist and aids in digestion and in swallowing. Saliva contains the enzyme, *ptyalin*, which changes starches into soluble sugars. For this reason food should be thoroughly chewed, so that it may be well mixed with saliva and thus partly digested before it reaches the stomach.

STUDENT REPORT

Where the Food Is Digested

	In the Cell	In the Leaf	Primitive Digestive Tube	Stomach	Mouth	Digested by Enzymes
Paramecium						
Hydra . .						
Frog . . .						
Man, etc. .						
Bean . . .						
Yeast . . .						

LABORATORY STUDY

Digestion of Proteins and Fats. — Study food and food tests. Artificial gastric juice is easily prepared by taking $\frac{1}{2}$ gram of pepsin, $\frac{1}{10}$ cc. of strong *hydrochloric* (hī-drŏ-klō′rĭk) acid and adding 50 cc. of water. Take white of egg that has been cooked and subject it, in a test tube, to the above mixture. A variety of tests should be made, with and without heat (100° F.), with and without the acid. Pancreatic juice is made by uniting 15 grams *sodium* (sō′dĭ-ŭm) *carbonate* (kär′bŏn-āt), 5 grams *pancreatin* (păn′krē-ă-tĭn), and 100 cc. water. The action of this fluid may be tested as above on the fats, as olive oil; on starch, as flour; and on proteins, as raw lean meat or milk. Also examine several of the common articles of food to determine to what class of foodstuffs they belong.

237. Absorption of Food. — The absorption of food in man and animals is the process of taking the digested foods

from the alimentary canal into the blood. Practically no food is absorbed in the mouth or esophagus, and but little in the stomach.

The absorption of food from the intestinal canal is done by small folds in the lining of the small intestine. To the naked eye, these folds appear as a covering of minute hairs, called *villi* (vĭl′lī). Their structure is shown in Figure 225.

The process of osmosis, which has been so frequently referred to in Part I, is the chief factor in the passing of the food into the blood vessels. This process is assisted by the action of the living cells in a manner not well understood.

The digested proteins and sugars pass directly into blood vessels which lead to the liver. In the liver, these blood vessels unite to form the *portal vein*, which is divided into minute branches that distribute the blood to the cells of the liver. As the blood thus passes among the liver cells, the larger part of the sugar is changed into *glycogen* (glī′kō-jĕn), an animal starch, and stored temporarily in the liver cells. This stored-up starch, glycogen, does not yield energy to the body. It is given out gradually from the liver and changed back into sugar and is built into protoplasm and thus yields energy to the body. This work of the liver results in keeping a uniform amount of sugar in the blood.

The fats pass into certain distinct vessels, *lacteals* (lăk′-tĕ-als), which in turn open into larger ones. Eventually these vessels unite to form a large duct — the *thoracic* — which empties into one of the veins near the heart. This food is now in the blood stream and is carried to the individual cells of the body. Each cell takes the kind of food which it needs, and by a series of changes, as yet only partly known, makes the food into living protoplasm. Circulation is given in more detail in the following chapter.

The indigestible part of the food is not absorbed, but continues to move through the small intestine into the large intestine, and on through the rectum. During this progress

much moisture is absorbed, especially in the large intestine, which leaves the "undissolved food" harder and harder. The regular removal of the unused part of the food, *fæces* (fē′sēz), is of much importance in maintaining health, because the bacteria living in the digestive tract cause the waste material to decay, and the poisonous substances thus formed are injurious when absorbed into the blood.

FIGURE 231. — X-RAY PHOTOGRAPH OF LARGE INTESTINE OF MAN SHOWING APPENDIX.

The constrictions are natural.

Foods normally remain in the stomach from one to five hours, and in the small intestine about four hours; while they may be from six to twenty-four hours in passing through the large intestine.

LABORATORY STUDY

Demonstration of Necessity for Digestion of Starch. — To make this demonstration it will be necessary to have an apparatus to demonstrate osmosis. There are several kinds. One of the simplest consists of a thistle tube with a piece of parchment tied over one end. This can be suspended in a dish of water. Place some starch paste in the tube, and after several hours test for starch with iodine. If your parchment is tight, no starch will have passed through and into the water. This experiment shows that starch cannot be absorbed until digested because materials that will not pass through such a parchment will not pass through the mucous membrane of the intestine.

238. The Hygiene of Eating. — We become hungry each day and feel relieved only after eating. A person frequently eats a large meal because of an extra amount of work that is to follow. But is he helped to do the extra work? Probably not, for the strength to do the work of to-day comes from the

food eaten yesterday, or possibly the day before yesterday. The food, even after digestion is completed, must pass through many changes before it is built up into protoplasm. The actual building of the food into protoplasm is the process for which the word *nourishment* is used, and it should not be confused with *absorption*.

Students and professional men use their brains more than their muscles, but they require protein to repair nerve waste just as laborers require proteins to feed their tired muscles. Unless students and professional men exercise their muscles, they do not feel vigorous and eager for their work. On the other hand, unless the laboring men exercise their brains, they do not do their work as well as they might. The proper amount of exercise varies with the individual. The best way to prevent indigestion is to have regular habits of eating and exercising.

239. Indigestion. — Few children who have an opportunity to romp and play out-of-doors and have plenty of simple and plain food ever experience any ill feeling in the digestive canal. However, as children grow older, exercise less, and eat richer food, they may suffer much inconvenience from indigestion.

Indigestion is a condition which rarely extends to all parts of the digestive canal; it is located either in the stomach or in the small intestine. This may indicate that certain kinds of food are not properly digested. Indigestion may be caused by eating the wrong kinds of foods or by overloading the stomach. If the food is chewed thoroughly, the appetite is usually a safe guide as to the amount needed by the body. Moreover, food thoroughly chewed is more easily acted upon by the digestive fluids.

To some people certain foods are indigestible at all times, while other foods are indigestible only at special times. We should learn to understand our bodies in this particular. Some of the causes of indigestion are: lack of sufficient regu-

lar exercise, too much rich food, and the failure to drink enough water.

There are in the market many tablets and remedies for indigestion, which may, for example, contain pepsin and pancreatin. Now we know that these substances when found in the pancreatic fluid act in an alkaline medium. As these tablets must first pass into the stomach, which is an acid medium, the action of the pancreatin is probably destroyed long before the remedy reaches the intestine, where it would naturally act. This means that such tablets are largely useless, and it is one of the reasons why many doctors believe that digestive tablets are doing more to cause indigestion than they do to help it. There are only a few commercial tablets made which act on the undigested foods of the intestine. No medicine, in fact, can give permanent relief to indigestion. Predigested foods, an attempt to relieve indigestion, serve a useful purpose in cases of sickness, but in our regular life should be used sparingly, because they do not give the digestive organs the proper amount of work to do.

240. Effect of Alcohol and Narcotics on Digestion. — The lining (mucous membrane) of the stomach and intestine is delicate and tender, and it contains thousands of cells which secrete the gastric juice, and many more thousands that help to digest the food. When alcohol comes in contact with these delicate cells, it prevents them from doing their normal work. The result is that food is not properly digested.

Indigestion Disguised by Alcohol but Not Cured. — It is a serious error to regard alcohol as a genuine remedy for indigestion or abdominal pain. It is true the sense of pain is sometimes abolished by alcohol and other narcotics, and as a result of this many a man believes that such substances aid his digestion, whereas they merely exert a numbing effect on the stomach nerves, and his indigestion is disguised rather than removed. In fact, instead of being cured the mischief

is increased, since digestion is retarded. Some digestive medicines contain enough alcohol to be injurious. Alcoholic drinks taken with meals make the food hard to digest because the alcohol makes the food tough. No narcotic is known to be beneficial to digestion.

OUTLINE

- Digestive organs
  - Mouth
  - Esophagus
  - Stomach
  - Intestines
    - Large
    - Small
  - Glands
    - Salivary
    - Gastric
    - Pancreatic
    - Liver
    - Intestinal
- Digestion
  - Mouth fluids
    - Alkaline
    - Saliva
  - Stomach fluids
    - Gastric juice
      - Pepsin
  - Intestine fluids
    - Pancreatic juice
    - Bile
- Teeth
  - Care of
    - Brushing
  - Bacteria
  - Mastication
    - Saliva
- Absorption
  - Intestinal
    - Villi
  - Liver
    - Portal vein
    - Glycogen
  - Lacteals
    - Thoracic duct
- Hygiene of eating
  - Nourishment
- Indigestion
  - Cures
    - Chewing
    - Exercise
- Effect of alcohol on digestion

SUMMARY

Man has a definite set of digestive organs that are more highly developed than those of any other animal. These digestive organs prepare proteins, carbohydrates, and fats so that they pass into the blood. The blood is forced by the heart through definite blood vessels. The study of food is important because we require food in order to live. The cost of food and the amount needed are problems that science is helping to solve.

QUESTIONS

What do man and other animals require in order to grow? Name the kinds of foods. What is the value of protein? Of carbohydrates? What is a Calorie? What are food substitutes? Name several ways in which the supply of food can be increased. What does cooking do to foods? Why is this important? What is digestion? What is indigestion? Absorption? How are the cells of the body fed?

CHAPTER XXI

CIRCULATION AND ASSIMILATION

The brain may devise laws for the blood.
— SHAKSPERE

241. Blood. — The blood is the fluid which circulates through the heart, arteries, and veins, supplying nutritive material to all parts of the body. Blood is made up of a fluid (plasma) which contains cells or corpuscles (Latin, *corpusculum*, little body). The blood cells or corpuscles are of two kinds, red and white.

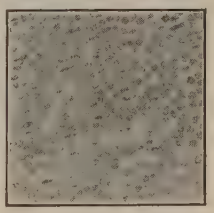


FIGURE 232. — PHOTOMICROGRAPH OF HUMAN BLOOD.

Compare with Figure 233.

The red corpuscles are colored with a substance called *hæmoglobin* (hē-mō-glō′bĭn: Greek, *haima*, blood; *globus*, ball). When a few of these corpuscles are examined through a microscope, they appear yellowish instead of red; but when a large number of them are seen in a mass, the red color is apparent. When the red cells are first formed, they have a nucleus which gradually disappears. As a result, the mature red corpuscles, unlike all the other cells we have studied thus far, have no nucleus. Red corpuscles are about $\frac{1}{3200}$ of an inch in diameter and $\frac{1}{12400}$ of an inch thick.

The red corpuscles carry oxygen from the lungs to the cells of the body. As soon as the oxygen in the respired air enters the blood, it unites chemically with the hæmoglobin contained within the red blood corpuscles. Here it remains

until it reaches cells that are deficient in oxygen, when it passes from the blood by osmosis to such cells. These cells take the oxygen and use it in the process of oxidation, which goes on continuously in every living cell. A good supply of red blood corpuscles is, therefore, necessary, if the cells of the body are to have a sufficient supply of oxygen. The feeding of the cells with oxygen is one part of respiration.

At the same time that oxygen is received from the blood by the body cells, carbon dioxide is given off. Again osmosis explains the method of this transfer. Most of the carbon dioxide is carried by the plasma, although some of it unites with the hæmoglobin.

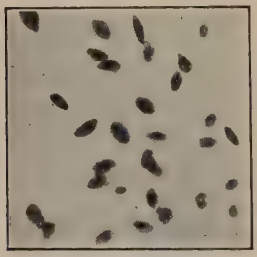


FIGURE 233. — PHOTOMICROGRAPH OF BLOOD OF FROG.

The minute black spot in each corpuscle is the nucleus. The nucleus is absent in human red blood corpuscles.

The white blood corpuscles are a little larger than the red and are much like the amœba in that they are colorless and can change their form. They move about in the body and often leave the blood vessels and collect at one place to aid the body in destroying disease germs. The white blood cells eat these disease germs in just the same manner that the amœba or paramecium eats bacteria.

The blood plasma has its source in the liquids taken into the body. It is straw-colored and varies in composition from day to day, and hour to hour. It contains the foods on their way to the cells, and waste products on their way to the kidneys, lungs, or skin. The volume of blood in the average person is about six quarts.

242. Clotting of Blood. — When the blood is exposed to the air it forms a clot. This is a peculiarity of blood. If it were not for this property of blood, animals would bleed to death from even a slight cut. In some warm-blooded animals, the blood clots more quickly than in man. Man is

able by pressing upon the blood vessels or by tying them to assist the process of clotting and prevent hemorrhage (hĕm′ôr-rāj). Naturally the blood does not clot except when exposed to the air, when fibrin threads are formed from the fibrinogen (fī-brĭn′ō-jĕn) of the plasma of the blood. These threads hold the red and white corpuscles. After a short time the whole mass shrinks, squeezing out the fluid part of the blood, and the semi-fluid mass that remains is the clot.

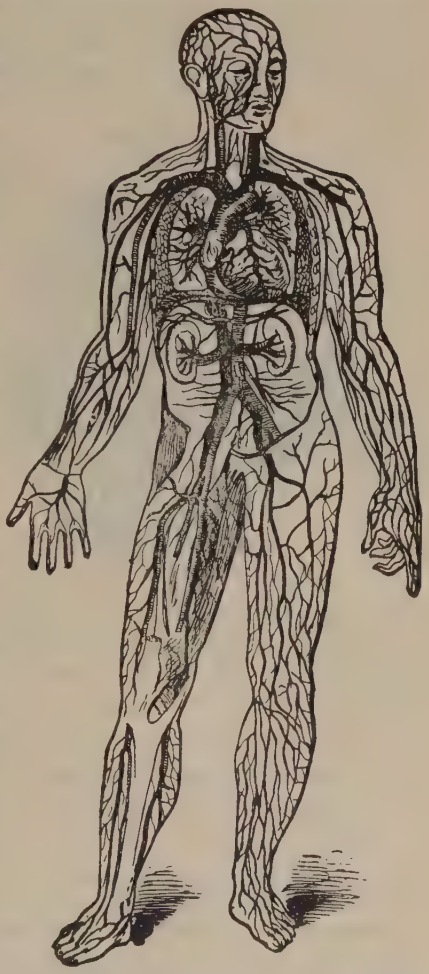


FIGURE 234. — ORGANS OF CIRCULATION. Veins, black; arteries, with transverse lines. Left side of figure shows superficial vessels while right side shows deeper vessels.

243. Temperature of the Blood. — The normal temperature of the body of an adult is about 98.6 degrees, although there are a few healthy persons who regularly have a temperature either below or above this average. This is known as *blood heat*, since it is maintained evenly throughout the body by the

blood. Of course this temperature may be lowered in the ears, fingers, toes, and so on by exposure, and it may be raised by fever. But normally the temperature (usually taken under the tongue with a clinical thermometer) should be about 98.6 degrees. When it is higher than this, the patient is said to "have a temperature," and it is a sign that something is wrong.

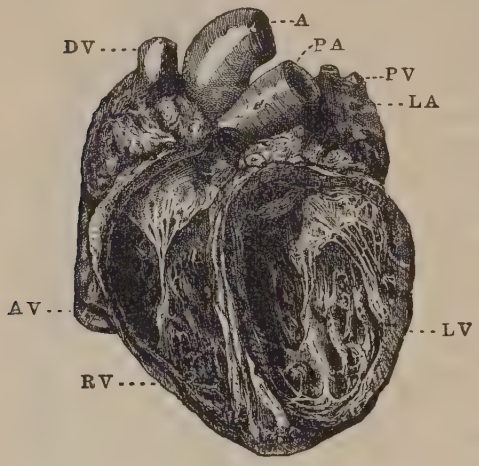


FIGURE 235. — THE HUMAN HEART.

A, aorta; *PA*, pulmonary artery; *PV*, pulmonary vein; *RV*, right ventricle; *LA*, left auricle; *DV*, descending vein; *AV*, ascending vein; *LV*, left ventricle.

244. Heart. — The blood is carried from the heart to all the cells of the body and back to the heart again and again. This organ serves as a pump to force the blood along. It is about the size of the fist and has strong muscular walls. In a healthy person, it contracts about seventy times a minute. It is obvious, therefore, that the work which the heart does is very great.[1]

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[1] "The work the heart does during the day is about equal to the energy expended by man in climbing to the top of a mountain 3,600 feet high. Assuming that the man weighs about 150 pounds, this would be equal to an amount of energy sufficient to lift 90 tons to a height of three feet. The work of the left side is greater than that of the right, since the former has to drive the blood all over the body, while the latter has only to force it to the lungs, which are near by. For this reason the muscle walls of the right ventricle are much thinner than those of the left ventricle." — CONN AND BUDDINGTON.

The heart is located in the *thoracic*, or chest, cavity, a little to the left side and between the lungs. It is a cone-shaped organ, inclosed in a membranous bag called *pericardium* (pĕr-ĭ-kär′dĭ-ūm: Greek, *peri*, around; *cardia*, heart). It has four chambers: two ventricles and two auricles (see Figure 235). A strong wall running vertically separates the right ventricle from the left ventricle, and a partition with valves or gates separates the ventricles from the auricles above. The auricles are virtually reservoirs in which the blood is stored until the ventricles, which are the strong walled divisions of the heart, are ready to propel the blood either to the lungs or through the rest of the body.

Before we follow out the circulation of the blood, the meaning of three words must be clearly defined. *Artery* is the name given to the blood vessels which carry blood from the heart. *Vein* is the term applied to the vessels which return blood to the heart. There is little structural difference between the veins and arteries except that the walls of the arteries are thicker, and there are no small valves as in the veins. As the branches of the arteries become minute, the walls are much thinner, thus allowing the food and oxygen to pass more easily to the individual cells. These minute branches are called *capillaries* (Latin, *capillus*, hair). (See Figure 236.)

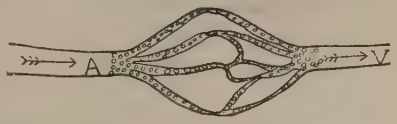


FIGURE 236. — DIAGRAM OF CAPILLARIES.
The artery breaks up into minute branches, the capillaries, which in turn unite to form veins.

The Pulse. Every time the heart beats the blood is forced into the arteries in waves which can be felt in the wrist or neck by placing the finger over an artery. The wave is called the *pulse*. By counting the number of waves each minute, the rate at which the heart beats is determined. When a person runs or takes violent exercise, the pulse rate increases. A similar increase in the pulse rate occurs when we

become angry or excited. It is advisable to know what our usual pulse rate is, for an increased pulse rate is sometimes an indication of approaching illness.

Closely associated with the pulse is the additional condition known as *blood pressure*. Blood pressure is the force with which the blood pushes against the walls of the arteries with every heart beat. Special appliances have been devised which accurately measure the amount of this pressure. The information thus revealed to the skillful physician is often very important.

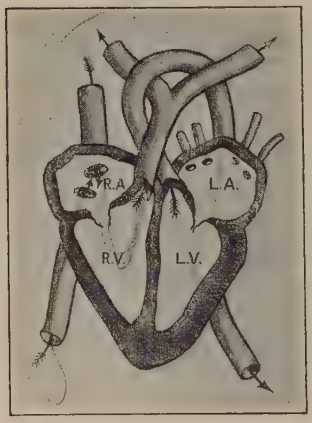


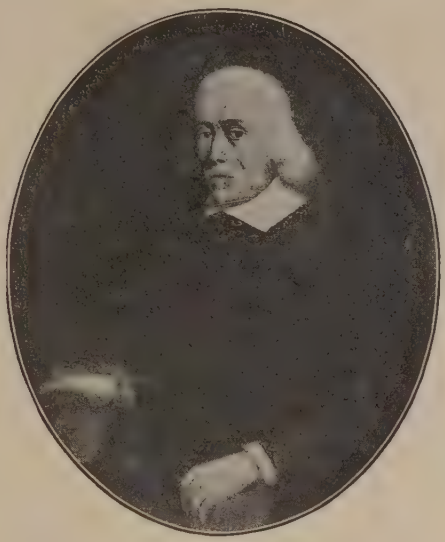
FIGURE 237. — HEART.

R.V., right ventricle; *L.V.*, left ventricle; *R.A.*, right auricle; *L.A.*, left auricle. The arrows indicate the direction that the blood takes. Describe its course through the heart.

HOME PROJECT

Experiments on Pulse Rate. — Count the number of beats per minute by placing the fingers on the wrist. You will need to repeat this count several times because you are not experienced in such observations. It is best to make the count on some one other than yourself. After you have been able to get about the same number of pulse beats per minute in two counts, have the person run upstairs or hop on one foot fifty times, then make your count again. The number will be increased as a result of the exercise. Compare the rate of the pulse when standing, after sitting a short time, when lying down, and the first thing in the morning. If you were to have your pulse taken just after getting angry or excited, you would also find that it has increased over its regular rate. What conclusions do you draw from these observations on your pulse?

245. Pulmonary Circulation. — The *right* ventricle, after it receives the blood from the *right* auricle above, contracts and forces the blood into a pulmonary artery which has at its farther end two branches. One of these goes to the right



William Harvey (1578–1667) began his studies at a period when science was not in good standing. The study of the structure of the human body was just being undertaken anew after a period of nearly twelve hundred years of neglect.

He was a very industrious student and his great classic was the result of many years of painstaking dissections. A free translation of the title of his remarkable book gives us the following: "An Anatomical Disquisition on the Movement of the Heart and Blood in Animals."

Harvey was the first one to describe the blood as moving in a circuit in the body and to state that the beating of the heart supplies the propelling force. After his brilliant dissections, man learned for the first time the difference between a vein and an artery and learned how to stop bleeding. He also made notable contributions to knowledge about the development of animals and their activities. True ideas about secretions, respiration, and the distribution of food in the body began as soon as the exact course of the blood was known. This is the reason why Harvey's discoveries are of such historical importance.

lung and the other to the left lung. These two branches subdivide in the tissues of the lungs until the blood is forced into minute capillaries which everywhere occupy the lungs. It is in these small capillaries in close contact with air spaces that the blood receives its new supply of oxygen and gives off its carbon dioxide. Finally these capillaries flow into veins which unite eventually and return to the left auricle. The blood is now ready to enter the *left* ventricle and be pumped through the system.

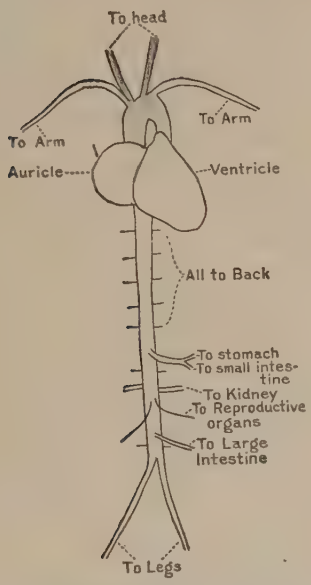


FIGURE 238. — MAIN ARTERIES OF MAN.

Compare with Figure 239.

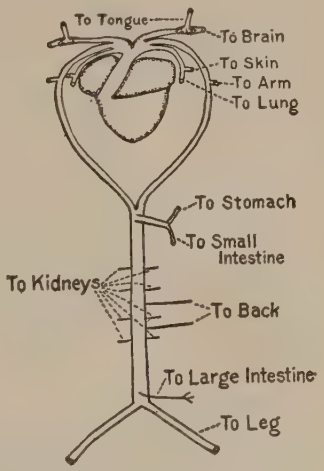


FIGURE 239. — MAIN ARTERIES OF FROG.

This is the pulmonary circulation, and by it the blood is purified, *i.e.*, it has lost much of the carbon dioxide and secured a fresh supply of oxygen. Its color has changed from a bluish red to a bright red.

246. Systemic Circulation. — From the left ventricle the blood is forced by its contraction through the aorta,

the largest artery in the body. The aorta divides at its base into two small arteries which carry the blood through the heart tissue and supply this with food and oxygen. Farther up the aorta branches into other arteries, some leading to the arms, some to the head, some to the trunk of the body, and others to the legs, so that all of the body is supplied with blood from the subdivisions of the arteries. The small arteries subdivide into capillaries, which penetrate to all the cells of the body and supply them with oxygen and foods in solution. These capillaries are so very numerous that in a piece of muscle with a cross section the size of an ordinary pin, there are about eight hundred of these microscopic blood vessels. A recent investigator states that the blood vessels of an average-sized man, if placed in a continuous straight line, would reach around the globe two and one half times. Because of their great numbers and consequent large surface, the capillaries can carry nourishment and oxygen to the tissues, and readily remove the waste. The capillaries conduct the blood from the arteries toward the smaller veins, which then become larger after the manner of the river system which is filled up by numerous tributaries. Eventually these veins carrying the blood toward the heart reach the right auricle through two main veins. This is the systemic circulation, and during the movement of the blood it has given up much of its supply of oxygen and lost much of its food value, which has been taken from it by the cells.

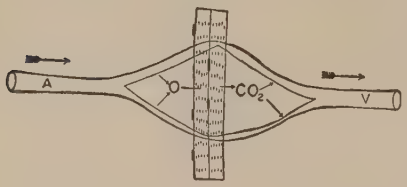


FIGURE 240. — DIAGRAM OF ARTERY, CAPILLARY AND VEIN.

As the blood flows through the capillaries of a voluntary muscle, for example, oxygen and other food products are given off to the muscle cells, and carbon dioxide and other wastes pass off from these same muscle cells into the capillaries on the way into the veins.

Portal Circulation. — The portal circulation includes the portion of the systemic circulation which courses through the liver and digestive regions and then returns to the heart. In the liver the blood takes up foods in solution.

Thus it will be seen that the composition of the blood changes as it passes through the various organs of the body, such as the skin, muscles, and stomach. The capillaries supply the substance necessary for the secretions of the glands; in the small intestine they absorb the elements of digested food; in the lungs they take up oxygen and give off carbon dioxide; and in the kidneys they throw off the waste products they have collected.

FIGURE 241. — DIAGRAM OF A VEIN SHOWING THE VALVES.

In which direction does the blood flow in this diagram?

The process by which each part of the body takes from the blood the food element that it needs is called *assimilation.*

247. Lymph. — As the blood flows through the capillaries, part of the plasma passes through the thin walls into the spaces between the cells and bathes the cells. This fluid which escapes from the capillaries is called *lymph*

FIGURE 242. — SUPERFICIAL LYMPHATICS OF ARM AND HAND.

(lĭmf). It is composed of digested food, water, and other substances. The cells assimilate the food which they need and cast back into the lymph the wastes which they have

formed in the process of growth and repair. These spaces between the cells are small and irregular in shape. The spaces, however, form a sort of mesh, or net, the parts of which join, forming larger vessels, and finally all the lymph is collected into two large vessels which open into veins.

Thus there is the *lymphatic circulation*, which differs from that of the blood in several ways. (1) There is no special organ for forcing the lymph along, the circulation depending mainly upon the movement of the muscles. (2) The lymphatic vessels are imperfect in the beginning, being only irregular spaces. (3) The lymph contains no red corpuscles and only a few white corpuscles.

248. Cuts. — Since every part of the body inside the skin is traversed by blood vessels, we cannot injure any part without breaking some blood vessels. A small cut causes the blood to flow only from capillaries, and it flows slowly and in small quantities. If a vein be cut, the blood will be dark in color, and will flow in larger quantities, but steadily. A severed artery sends out bright red blood in waves corresponding to the beat of the heart. To stop the flow of blood from a vein, compress the vein beyond the cut; from an artery compress the artery between the cut and the heart. In either case remain quiet to aid the blood to form a clot.

249. Exercise. — The object of a circulatory system and of a circulatory fluid is to supply every cell in the body with food and to carry away the waste. The more active the process of circulation, the more perfectly is this object accomplished. It is the common experience that the heart beats more rapidly, the lungs work harder, and the body becomes warm after a few minutes of vigorous exercise. These changes have a decidedly beneficial effect upon building up the body and removing the wastes.

Fainting. — Fainting is due to an insufficient supply of blood in the brain. This lack of blood may arise from several causes, but the most common is some disturbance

of the digestive processes, which causes the heart to beat too slowly. A fainting person should be placed flat on his back, if possible, with his head slightly lower than the rest of his body, and should be given plenty of fresh air. A dash of cold water in the face, or a bottle of ammonia held to the nostrils, is often helpful in restoring consciousness.

250. The Effect of Drugs and Alcohol. — Some drugs cause the blood to flow more rapidly, others more slowly. Coffee makes the heart beat faster and also makes some of the arteries smaller. That is why it is called a stimulant.

While alcohol may increase the activity of the heart, the effect of taking large amounts is to weaken the heart action. If taken only in small amounts, the heart sometimes shows a slight increase in its rate of beating, but this occurs only when the brain becomes excited, and if the person is kept quiet no change in the heart beat is noticeable. Thus the primary action is on the brain.

Another effect of alcohol is to enlarge the small blood vessels in the skin. This produces a flushed skin, and a feeling of warmth, and gives a false sensation of increased circulation. It sends more blood through the skin with consequent extra loss of heat. This action is due not so much to stimulation, as to the relaxation of the muscles. Thus there is a decrease of activity rather than an increase, even though the blood does flow a little more rapidly through the skin. For these reasons alcohol cannot be properly called a stimulant to the circulation.

When alcohol is introduced into the blood, the forming of the clot takes place more slowly, though alcohol taken in the usual beverages will not entirely prevent the clotting of blood.

251. Ductless Glands. — There are a number of glands in the body that discharge their secretions directly into the blood and not into the intestinal cavity as the pancreas and liver do. Such glands are commonly described as the duct-

less glands, or the glands of internal secretion. The best known of these are thyroid, adrenal, thymus, and pineal. There is a considerable number of these glands and all play an important part in the normal growth and activity of our bodies. We are just beginning to understand, in part at least, their importance, but a great deal more must be discovered before we can accurately describe the influence of these glands. Sometimes they manufacture more secretions than they normally should, and sometimes they fail to set free the usual amount. Excessive growth such as we find in giants and excessive fatness are attributed to an oversupply of certain of these internal secretions; while dwarfishness and some forms of imperfect growth in children are believed to be due to an inadequate amount of these secretions.

The thyroid gland is found in the neck just below the voice box. It consists of two parts, that are united by a thin strip passing across the front of the air tube. The normal thyroid is small and inconspicuous. When it becomes greatly enlarged the swelling is known as *goiter*.

The adrenal glands are two small bodies which are situated just in front of the kidneys. It has long been known that they are necessary to life. If they are destroyed, as sometimes happens in one of the many forms of tuberculosis, serious consequences follow, and the skin takes on a dark color. That, with other symptoms, gives rise to what is known as Addison's bronze disease.

252. Hormones. — The glands of internal secretion produce substances which have been described as chemical messengers or *hormones* (hor′mo-nēz). Such bodies are produced in some definite gland but have to be carried to other parts of the body before they can produce any effect. These chemical messengers are very important in stimulating the flow of gastric juice and the secretions of the pancreas, as well as aiding in the activity of the thyroid gland.

A great deal of emphasis is placed to-day upon the importance of the chemical messengers of the body in regulating its normal activities.

OUTLINE

- Blood
  - Corpuscles
    - Red
    - White
  - Clotting
    - Fibrinogen
  - Temperature
- Heart
  - Location
    - Chest
  - Parts
    - Auricles
      - Right
      - Left
    - Ventricles
      - Right
      - Left
  - Pulse
    - Blood pressure
- Circulation
  - Pulmonary
    - Right auricle
    - Right ventricle
    - Lungs
    - Capillaries
    - Left auricle
    - Left ventricle
  - Systemic
    - Left ventricle
    - Aorta
    - Arteries
    - Capillaries
    - Veins
    - Right auricle
  - Portal
    - Liver
    - Digestive organs
- Lymph
  - Circulation
- Cuts
  - Treatment
    - Arteries
    - Veins
- Exercise
  - Effects
- Fainting
  - Reason for
  - Treatment
- Effects of alcohol
  - Weakens heart
  - Enlarges blood vessels
  - Relaxes muscles
- Ductless glands
  - Thyroid
    - Goiter
  - Adrenal
    - Bronze disease
- Hormones

SUMMARY

The blood of man consists of corpuscles and plasma. The hæmoglobin in the red corpuscles unites with the oxygen in the lungs and carries the oxygen to all parts of the body as the blood flows through the numerous arteries and capillaries. The waste gas, carbon dioxide, is also carried by the blood from the cells to the lungs, where it is released to the air.

The heart of man is highly developed and consists of four chambers, those in the same side connected by valves. The work that the heart does in pumping the blood is very great. It is easy to modify the pulse rate by lessening or increasing your natural activities. The ductless glands pour out their secretions into the blood. These secretions are known as hormones or internal secretions. We are just beginning to realize that they play a very important rôle in our normal activities.

QUESTIONS

What is blood? What are its parts? Which of its parts are dead? Which are alive? Explain the work of the blood. What is the relation of the lungs to this work? Why is it important to know about the way blood flows in arteries and veins? What are ductless glands? What do some of them do for us?

CHAPTER XXII

EXCRETION

The kidneys are the filters of the blood.
— Bacon

253. Excretion. — Every animal uses energy in carrying on its work. During this process a certain amount of waste substance is produced, which has to be removed from the body. The kidneys, lungs, intestines and skin are the chief organs which assist the body in getting rid of this waste. When any part of the living cells is broken down in the simple act of living, a waste product results. By osmosis these waste products enter the blood and are removed by the lungs, which give off carbon dioxide, by the sweat glands in the skin, and by the kidneys, which remove the wastes that contain nitrogen.

The sweat glands and kidneys are usually regarded as the excretory organs of man. These organs remove from the blood the wastes which have been excreted by the cells of the body. The excretion from the living cells is one of the fundamental life processes of all plants and animals.

254. Kidneys. — The kidneys are two bean-shaped organs located in the abdominal cavity, one on each side of the " small " of the back. Each is about four inches long, two and a half inches wide, and half an inch thick. The color is a dark red. The kidney is made up of two layers, the outside or *cortical*, and the inside or *medullary*. Each layer is composed of many small tubes (*tubules*) which open into an area called the *pelvis*, the space within the kidney.

The pelvis continues into a duct (*ureter*), and from each kidney the ureter passes into the *bladder*. A small duct (*urethra*) (ū-rē′thrȧ) connects the bladder with the exterior of the body.

Each tubule in the kidney is in close relation with the blood capillaries. At the place where this close relation is found, *glomerulus* (glŏ-mĕr′u-lus), the walls of the capillary and the walls of the kidney are very thin. Through these thin walls a large amount of water filters out of the blood into the tubes. At the same time waste material which contains nitrogen, salts, and other organic wastes is removed. If these wastes are not removed, they create toxins which poison the body.

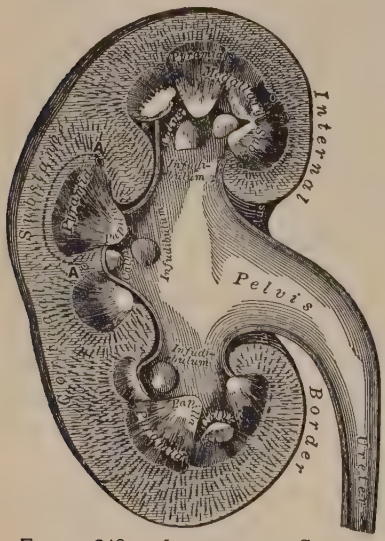


FIGURE 243. — LONGITUDINAL SECTION OF KIDNEY.

255. Lungs. — The carbon dioxide that passes from the blood by osmosis into the lungs is a waste product. Associated with this waste there is found a rather large amount of water, sometimes as much as a pint in twenty-four hours. The importance of the lungs in giving off water vapor which is a waste product is regarded by some physiologists as greater even than that of the skin.

256. Intestine. — The excretion wastes from the intestine are not easily defined. The several digestive secretions which are not absorbed may be regarded as waste products after they have caused the different digestive changes. Of these a small portion remains in the intestine. The bile pigments

may be especially mentioned as excretions that pass from the body through the intestine. The real excretions of the body should not be confused with the indigestible part of the food which is not taken up by the blood and which passes out through the large intestine as fæces.

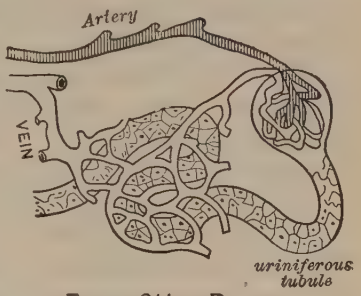


FIGURE 244. — DIAGRAM.

Showing relation of artery and vein to portion of minute kidney tube (uriniferous tubule).

257. Skin. — The skin covers and protects the voluntary muscles, regulates the body temperature, gives off waste matter, and acts as a general sense organ. Thus we see that it is incorrect to think of the skin simply as an organ of excretion. In order to understand just how wastes are removed by the skin, it is necessary to study its parts. The outer layer of the skin is called the epidermis (Figure 245) and is chiefly composed of dead cells. These outer cells are constantly breaking off, a process which is most apparent in the case of sunburn. Whatever pigment or coloring matter there is in the skin is located in the inner cells of the epidermis. The amount and kinds of pigment determine whether a person is of light or dark complexion, white, black, or yellow. These inner cells

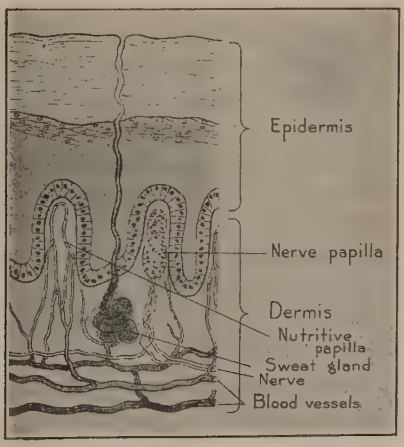


FIGURE 245. — DIAGRAM OF SKIN.

are constantly growing new cells to replace the cells which scale off.

The nails and the hair arise in the outer layer of the skin.

Other structures which arise in the same way are the scales of fishes and snakes, the hoofs and horns of cattle, and the feathers of birds.

The inner layer of the skin is the *dermis;* it contains blood vessels, nerves, connective tissue, the sweat glands, and sense organs of touch, pain, heat, and cold. It is estimated that there are over two million sweat glands in the skin of man. These are the excretory organs of the skin, and their work is to eliminate waste substances from the blood and to keep the body temperature normal (98.6° F.) by regulating the amount of perspiration excreted. The amount of perspiration is influenced both by the temperature of the body and of the air. The evaporation of perspiration keeps the body at the normal temperature.

The skin is attached to the body by a loose layer of connective tissue in which fat is deposited. This is known as the subcutaneous layer of fat. This layer becomes very thick in corpulent people.

258. Importance of Bathing. — "A clean skin is a healthy skin," and we may add that a clean skin is the only skin that can properly carry on all of its activities. Bathing and exercise serve to keep the skin clean and healthy.

No exercise is really complete unless it is followed by a bath, for during exercise the pores of the skin have been opened and it has been active and perspiring. The best time to take a bath is in the morning on rising or as soon as exercises have been taken. A cold bath which does not last more than five or six minutes is best. Hot baths are weakening and depressing. Regular habits of bathing, as also of eating, sleeping, and exercising, are indispensable hygienic measures and help to keep us well.

259. Adaptations in Excretory Organs. — You have only to review what has been said about the structure of the kidneys, sweat glands in the skin, and the minute air sacs in the lungs to recall that in each of these organs the cells are especially adapted to carry on the work it does. The thin layers of cells in the lungs permit the gas, carbon dioxide, to pass through readily. The cells in the sweat glands are adapted to removing water from the blood, while the kidney cells act largely as filtering cells. This adaptation in the kidney cells is more evident, if we recall that the cells of the liver manufacture urea, which consists of a large amount of the nitrogenous wastes of the body. The urea is discharged from the liver into the blood and removed from the blood by the kidneys.

260. Importance of Excretion. — Unless the several organs of excretion do their work properly the wastes of the body accumulate. These wastes are poisonous, and harmful results must follow if they are allowed to remain in the system. A skin which is not healthy cannot be expected to hold healthy nerve endings nor to do its work as it should. Overeating or eating too much meat places an extra burden on the kidneys because the body absorbs only as much nutriment as is needed and can be stored as fat. The rest has to be removed. This makes the work of the kidneys especially hard. Regularity and moderation in eating, as in all habits, are two excellent rules to follow. The removal of wastes from the body is influenced by the amount of water taken daily. There are few who drink enough water and very few who ever drink too much.

SUMMARY

Excretion is one of the fundamental life processes in all living things. In the higher animals special organs are present which remove these wastes. These are the kidneys, lungs, intestines, and skin. Unless the body is kept clean and healthy, the excretory organs do not do their work well. Each organ is adapted to removing the different kinds of

wastes. The best hygienic rule to follow is to eat with moderation, to eat and sleep regularly, to take sufficient exercise, to keep the body clean, and to drink plenty of water.

QUESTIONS

What is the meaning of excretion? Is this process present in the frog? In the crayfish? What are the special organs of excretion in the frog? In man? How are they adapted to doing their work? How may they be hindered from doing their best work?

CHAPTER XXIII

THE NERVOUS SYSTEM OF MAN

Back of the sound broods the silence,
Back of the gift stands the giving;
Back of the hand that receives,
Thrill the sensitive nerves of receiving.

— REALF

261. The Parts of Man's Nervous System. — The nervous system of man consists of the same general parts as the nervous system of the frog (see page 148). There is a brain and spinal cord, from which nerves extend to the special senses, the muscles, the heart, and the stomach. When the brain of man is compared with that of the frog, it is obvious that the cerebrum of man is proportionately larger. Although some of the other parts of the brain appear unlike the corresponding regions in the frog, scientists tell us that they are really the same.

262. Nerve Cells or Neurons. — The nervous system of man consists of many thousands of nerve cells or neurons which differ from all other cells in having more parts and branches (Figures 247, 248, 249). Examination shows that the nerve cells have a prominent nucleus surrounded by cytoplasm, which grows out into a number of branches called *fibers*. The shorter branches divide and form, together with the branches from the neighboring nerve cells, a mass of tangled fibers. There is usually one unbranched fiber, perhaps several feet long, which ends either in the skin, in some muscle, or in the spinal cord or brain. When this long fiber reaches the muscle or skin, it divides into several

fine branches. All these branches belong to the cell, so in this connection the word *neuron* includes all the branches, the nucleus, and the cytoplasm. It is the unit of the nervous system.

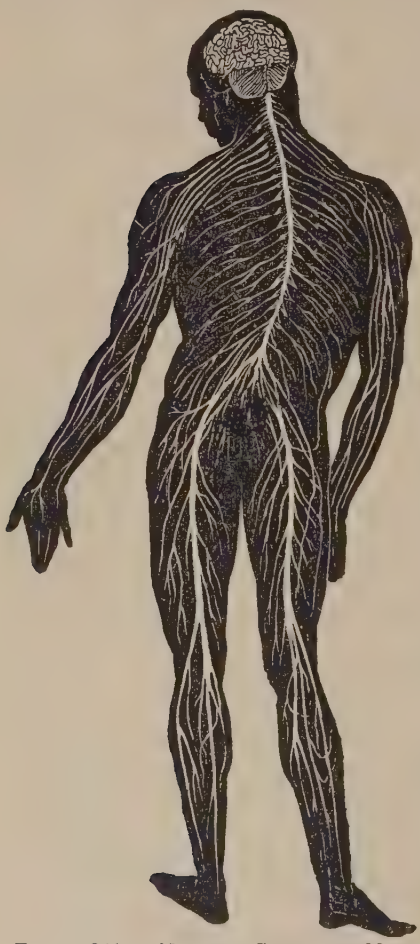


FIGURE 246. — NERVOUS SYSTEM OF MAN.

263. The Location of the Nerves. — The nerve fibers which have the same work to do occupy certain definite places in the brain and spinal cord. A student of the nerves can tell the route which the stimulus arising from feeling a pencil must travel before reaching that part of the brain where it is interpreted as a pencil; or the route over which the stimulus arising from tasting candy must pass before it is known to be that of candy. When we see the pencil or the candy, the route over which the sight stimuli of these two objects travel is not the same as that of the feeling of the pencil or tasting the candy. The nerve cells which interpret the stimulus arising from feeling the pencil or from tasting the candy or seeing the pencil and the candy

are probably not the same. We may say, therefore, that the spinal cord and brain are made up of many special nerve pathways which end in nerve cells that interpret stimuli.

The nerves which connect the central nervous system, that is, brain and spinal cord, with all parts of the body, consist of many long nerve fibers. Each nerve looks like a small white thread and is covered with a thick, fatty sheath (medullary sheath). In the living animal, this fatty sheath is white and the nerve fibers so covered are found to occupy a certain part of the spinal cord and brain. Thus, we get the name *white substance*. Other of the nerve fibers and cell bodies are not covered with a sheath and so have a gray appearance. Thus we have the term *gray substance* in connection with the nervous system.

FIGURE 247. — NERVE CELLS.

Stained to bring out the minute parts in addition to the nucleus.

The Central Nervous System. — In Figure 246 the nerves of the legs, arms, and trunk are all seen to be united to a central body, the spinal cord. There are nerves in the upper part of the neck and in the head region that unite with the large mass at the upper end of the spinal cord, the brain. The brain and spinal cord are known as the central nervous system. The brain is divided into the following parts: *cerebrum*, the most anterior; the *mid-brain*, to which the optic nerves join; the *cerebellum;* and the *medulla oblongata*, to which the nerves of hearing, tasting, and the facial nerves belong.

The cerebrum is the most important of the several regions of the brain. It regulates and controls all our nervous activ-

ities. The cerebellum gives tone and vigor to the contraction of the muscles and helps us to know when we are properly balanced and is hence known as the equilibration center. The remaining parts of the brain give off and receive nerves and transmit nerve stimuli to the cerebrum and cerebellum.

Thus each part of the nervous system has a definite function, and is adjusted to its environment by means of the different senses. These we shall study more in detail later in this chapter.

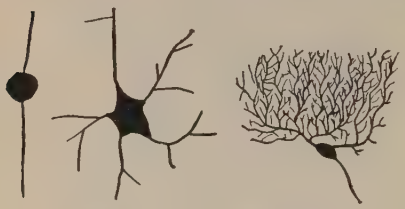


FIGURE 248. — NERVE CELLS.

Stained by the silver process which blackens all the parts. This is an excellent stain to show the branching processes.

The Sympathetic Nervous System. — This is made up of a double chain of *ganglia* (Greek *ganglion,* a knot), which are connected with each other by nerves and with the central or cerebro spinal system by fibers. From these ganglia many fibers run to the blood vessels of the heart and to the organs of the alimentary canal. When people die of shock, this is caused by the serious disturbance of the sympathetic system.

264. Growth of the Nervous System. — The nervous system of man, like all other parts of the body, has a definite beginning and grows in an ordered manner. Not only is this true in man, but also in the frog and fish. The tissue of the embryo, which is to grow into brain and spinal cord, gradually changes until the adult parts are formed. During this early period of growth, the nerve cells send out processes which become nerve fibers, so that at birth the nervous system is ready to go to work. Indeed, nearly all the nerve cells which the human being is ever to use are made before birth. These cells gradually become more active and the different parts of the brain work more perfectly as we go through the periods of childhood, youth, and maturity.

The brain becomes a more perfect working organ by making the brain cells do their specific work over and over and over, until each group of cells can be relied upon to do a definite thing.

While the nervous system grows naturally, its training is also important, for it may be said to be the organ of the mind. Habits may be formed as in the case of the rest of the body, by the selection and control of certain impulses and sensations.

265. Reflex Action. — Reflex action is the simplest form of nervous activity in man. For example, when the finger

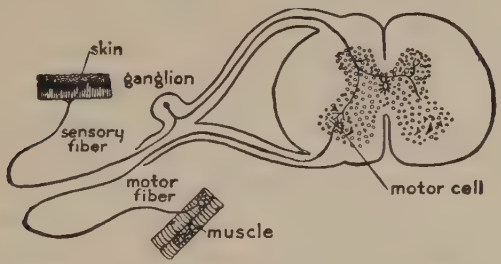


FIGURE 249. — DIAGRAM TO SHOW REFLEX ACTION.

The stimulus comes in contact with the skin and is carried to the spinal cord. It then passes to the motor cells which carry the order to the muscle. The same skin stimulus goes to several other parts of the spinal cord.

is placed on a hot stove and suddenly withdrawn the following actions take place. The heat stimulus affects the nerve endings in the finger and that stimulus is carried to the spinal cord. If this were all that occurred, the finger would burn, because this stimulus and the nerve fibers over which it travels have no control over the muscles. The removal of the finger is brought about by another set of nerve cells — the cells which have their fibers ending in the muscles of the hand and arm.

All these changes take place involuntarily, and the reaction to the stimulus is known as reflex action. Specific

names are used in describing these several changes; the nerve fibers which connect the skin with the spinal cord and brain are called *afferent* (ăf′fĕr-ĕnt: Latin, *ad*, to; *fero*, carry) fibers because the stimulus always travels towards the brain.

Their function is *sensory*, for they carry the stimulus to the brain. The fibers which connect the muscle with the brain or spinal cord are the *efferent* (ĕf′fĕr-ĕnt: Latin, *ex*, from; *fero*, carry) or *motor* fibers, because they carry their message away from the central nervous system. Their function is to produce motion. In the special instance we are studying, the heat stimulus causes the spinal cord to send a special message to the muscles of the finger, so that the latter is removed from the stove.

This is a typical illustration of the simplest way in which the nervous system works, but in most reflex actions there are other results. After the finger has been removed from the hot stove by reflex action, we soon realize that the skin is burned, the realization coming through the smarting sensation. This second stimulus has been carried to the brain, and we are now conscious of the stove, heat, burn, etc. If there were no afferent nerve fibers, the individual could not experience any pain when hurt.

The afferent and efferent nerves, whether in reflex or in general nervous action, never vary in the work which they do. The sensory afferent nerves form the only paths over which our information of the outside world travels to the brain. The stimuli which cause the different sensations, such as taste, sight, etc., have their individual paths and receiving organs. This is indicated by the fact that no other nerves than those of the ear are ever affected when we hear.

Reflex Action in the Frog. — The frog, like man, is able to act in a definite way. If any one approaches a frog while it is sitting on the edge of a pond, it jumps into the water, stirs up the mud, and then returns to the shallow water near

the place where it entered. The frog, in this case, acts as if it, or its ancestors, had learned that this is the best way to escape enemies. While this series of acts is called a habit, it is really a series of reflex acts which are similar to the reflex action described for man, and require the same nerve structures.

Reflex action is similar in all animals. The stimulus must be received by an afferent nerve, or some structure which can do the same work, and it must be transformed into a series of purposeful movements.

266. Rest and Relaxation. — We frequently read of some famous man who is able to do his work with but a few hours of sleep. But for the great majority of us, cutting short the hours of sleep soon renders us unfit to do our work. Sleep is nature's method of resting the body. The muscles even in their correct use have been under a long strain. The natural waste products caused by the varied activities have accumulated faster than they have been removed and the entire body is fatigued. Some people have urged that a change of activity is a rest, but this is only true in a very limited sense.

We spend about one third of our lives regularly in sleep, and this is the most complete form of rest. During the period of sleep the nervous system and muscles are in a reduced form of activity. We usually sleep more soundly during the early hours of the night.

It is customary to describe the accumulated wastes of our bodily activity as *fatigue toxins*. This means that these waste products, unless removed, act as poisons to the body. Whenever fatigue is severe and clearly defined we have to do with a loss of power. The usual fatigue is relieved by a single night's rest, but when it is not, the conditions soon become more serious and require medical advice.

Anticipation is a word that suggests either joy or fear to most of us. Under the usual conditions we look forward to

the pleasures of the day in school and, if happy, the work passes off with little difficulty. On the other hand, an unhappy state of mind produces just the opposite result, and the day's work is poorly done, with a marked increase in the amount of fatigue. The natural anxiety and fear that arises in the case of sickness in one's family may be so great as to disturb an otherwise good digestive system or prevent the proper concentration on study. It is unfortunate to yield to anticipated fear and anxiety, and we should cultivate the habit of thinking about the pleasures and the duties of each day.

Amount of Sleep. — Different amounts of sleep are required in the periods of youth, of maturity, and of old age. Youth requires more sleep than maturity because two requirements must be met: first, the restoration of the tissues that have been broken down during the day; second, the growth of new tissue as the body is increasing in size during youth. The mature person has only the first requirement to meet. In old age tissues are repaired more slowly and, therefore, more rest is necessary.

It is unwise to try to establish an exact law in regard to the requirements of sleep, for some individuals need more daily sleep than others. The statement is generally made that eight hours of sleep is sufficient for anybody. There are some who need more and some who are better off with less. A simple rule is to ask the question: How do you feel when you get up? Does the world look bright and full of promise? Are you anxious to be "up and doing"? If so, then you have had enough sleep.

267. Brain Efficiency. — While the efficiency of the brain depends upon mental training, in order properly to exercise the many functions of this organ at least three things are necessary: good food, sufficient sleep, and abstinence from alcohol and tobacco. We have already discussed the questions of food (page 298).

At a baseball game, you have noticed a boy catch a "fly" when it looked like a "home run," or how enthusiastic the crowd became when the pitcher struck out the last man with the bases full. The nervous system of each player was efficient in a critical test.

We all ride on street cars or railroads, but do you know that most of the men who run the street cars and trains have to pass an examination to determine whether they can be

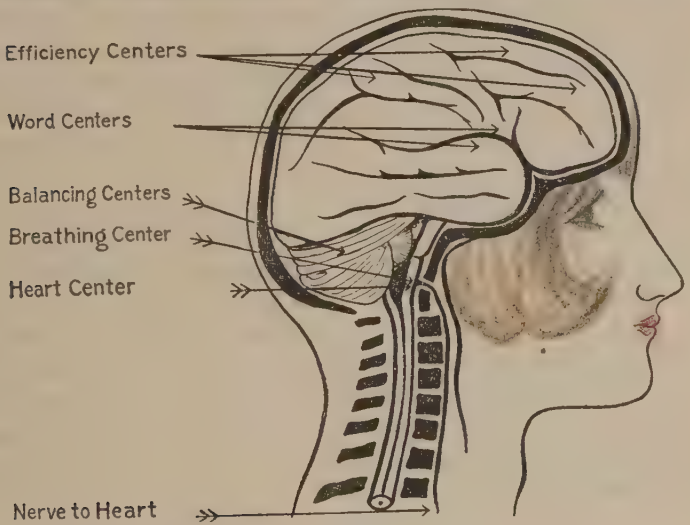


FIGURE 250. — BRAIN CONTROL.

trusted to do their work properly and well; *i.e.*, whether their nervous systems will stand the test?

The question of brain efficiency is illustrated by Figure 250. Long before birth the heart in the embryo begins to beat and is under the control of the nervous system. The part of the brain which superintends the heart is located in the medulla, where a special cluster of cells sends out nerve fibers which enter the heart nerve. These nerve cells are called the heart center.

The next nerve center to begin work is the breathing center, located close to the heart center, which controls the breathing. This does not become active until after birth.

About a year after birth, several more nerve centers become active in the child's brain. These are the ones which help him to walk. The cerebellum contains nerve centers which play an important part in walking and in learning to balance. The muscles which move the arms and legs are regulated by nerve centers in the cerebrum.

Soon after the child learns to walk, he begins to talk and learn words. The several nerve centers which now become active are all located in the cerebrum. These are the nerve cells which are necessary in speaking, hearing, reading, and writing words.

After the age of fifteen years the brain goes through important structural changes and the young person begins to do hard tasks well. It is difficult to locate the exact spots in the cerebrum where the nerve centers are that now become active, for they are widely distributed. These nerve centers may be called the efficiency centers and they are the last to develop. But as they become active, every one becomes skillful in respect to some one thing, although many years of training are necessary before the maximum of efficiency is reached.

The efficiency centers which are the last to become active and which require so much energy to train properly are the first to be affected by alcohol.

268. Structural Changes Due to Alcohol. — Definite changes are found in the protoplasm of nerve cells after the use of alcohol. These consist in a shrinking of the nucleus, the loss of the spindle-shaped (*Nissl*) bodies (Figure 247), the swelling of the cell, and the presence of vacuoles in the cytoplasm. It is also probable that some of the nerve cells are actually destroyed. These physical changes explain why the results are so great and why complete recovery of

mental efficiency in the drunkard is so doubtful. The modern point of view and the one which is becoming firmly established in the treatment of drunkards by physicians is that alcoholism is a disease.

In order to judge the success of a piece of work we must consider the quality and speed with which it is done. Kraepelin made the following experiment, the results of which show that both these elements in mental work are influenced by the use of alcohol.

Several men who were allowed to drink no alcohol utilized half an hour daily for six days in adding figures. Their ability to add increased each day. On the seventh day the work was begun under the influence of alcohol. In spite of the skill gained in the previous practice, their accuracy did not increase, but on the contrary began to decrease rapidly. On the nineteenth day the use of alcohol was stopped, and immediately an improvement in the work manifested itself; but on the twenty-sixth day, when the use of alcohol was resumed, a decided decrease in the power of adding manifested itself.

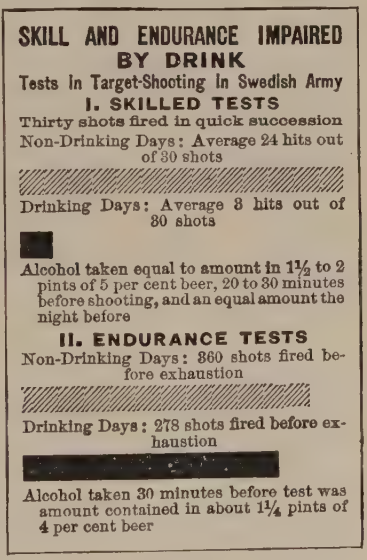

SKILL AND ENDURANCE IMPAIRED BY DRINK
Tests In Target-Shooting In Swedish Army
I. SKILLED TESTS
Thirty shots fired in quick succession
Non-Drinking Days: Average 24 hits out of 30 shots
Drinking Days: Average 8 hits out of 30 shots
Alcohol taken equal to amount in 1½ to 2 pints of 5 per cent beer, 20 to 30 minutes before shooting, and an equal amount the night before
II. ENDURANCE TESTS
Non-Drinking Days: 360 shots fired before exhaustion
Drinking Days: 278 shots fired before exhaustion
Alcohol taken 30 minutes before test was amount contained in about 1¼ pints of 4 per cent beer

FIGURE 251. — EFFECTS OF ALCOHOL.

It is difficult to estimate how efficient each of us may become in our life work, but one thing is certain, that if we use alcohol, we shall lose that perfect control over our nervous systems which enabled the two players in the preceding section to be so efficient in the ball game. It is also equally

certain that if we use alcohol, we shall find fewer men willing to employ us in places of responsibility, not only because of our lowered efficiency, but because of our unreliable judgment.

269. Sense Organs. — All the higher animals have eyes, ears, a nose, and a tongue. Each of these organs contains nerves specialized to respond to a certain definite kind of stimulus. The result of this specialization is that not only are these special sense organs complex in structure, but also the region of the brain which receives their messages. The ear nerve responds to a stimulus of air-waves of a certain length, and we say we hear a sound. The eye nerve is stimulated only by light. Each nerve and the brain cells to which it sends its messages have become so specialized that practically only one kind of reaction takes place. For example, all stimuli acting upon the eye nerves are interpreted as light.

The skin is a simpler sense organ than the eye or ear, and tells us of pain and touch and the difference between heat and cold.

Smell and Taste. — These two senses are closely related. The sense of smell is located in the nose, and the organs of smell are minute nerve cells scattered among the regular cells that line the nasal passageway. The olfactory nerve which carries smell stimuli to the brain is the shortest nerve in man.

Taste has already been described in connection with the digestive system on page 334.

270. The Eyes. — The eyes of all vertebrates have the parts arranged in a similar manner. The eyeball is roundish and is located in the eye sockets of the skull, which are termed *orbits*. There is an upper and a lower eyelid, and the remains of a third eyelid in the corner next to the nose. The front of the eye is covered by a transparent membrane, the *cornea* (kôr′nē-a); and the rest of the eye is surrounded

by a tough membrane, the *sclerotic coat*, or the *white of the eye*. Within the combined covering of the cornea and sclera are a number of structures which take part in receiving and transmitting the rays of light to the brain.

A cross section of the eye shows two more membranes in close relation to the sclerotic coat (Figure 252). The membrane in direct contact on the inside with the sclerotic layer is the *choroid* (kō′roid). The choroid coat is filled with blood vessels and pigment. Through this layer the food in the blood is distributed to the eye. The third layer or coat is the *retina*, which is composed of nerve cells and is nearly transparent.

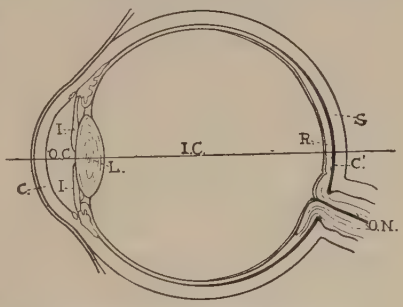


FIGURE 252. — SECTION OF EYE.

C, cornea; *C′*, choroid layer; *I*, iris; *I.C*, inner chamber; *O.C*, outer chamber; *L*, lens; *O.N*, optic nerve; *R*, retina; *S*, sclerotic coat.

The cornea and these three layers inclose two chambers which are separated by the *lens* (Figure 252). In front of the lens a curtain-like membrane, the *iris*, partly covers the lens, except for a round opening in the center which is called the *pupil*. The color of the eye, gray, black, blue, or brown, is due to the presence of pigment in the iris. The small front chamber is filled with a transparent fluid which is composed principally of water and is known as the *aqueous* (ā′kwĕ-ŭs) *humor*. The large back chamber is filled with a thin, transparent, jelly-like fluid, the *vitreous* (vĭt′rē-ŭs) *humor*.

In order that we may see any object, a pencil in our hand, for example, two general conditions must be present. The picture (image) of the pencil must be placed on the retina, and this picture must be carried to the brain by

the eye (optic) nerve. When these two conditions take place, we see.

As we have learned, the stimulus for the eye is always light. In physics we learn that the rays of light travel in straight lines. This fact explains why we cannot see around a corner. When the rays of light are made to pass through a glass lens, the rays which pass through the thin edges of the lens are bent and do not travel to the same place they would have reached had they not passed through the lens. In the same way light rays from an object pass through the lens in our eyes and are bent. This results in the image of the object, the pencil in this instance, being inverted on the retina. The light rays from the pencil stimulate the nerve cells in the retina, and this stimulus, after being carried to the brain, is interpreted to us as a pencil, though we do not know how stimuli travel on nerves.

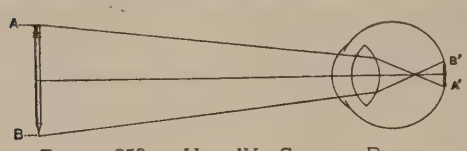


FIGURE 253. — HOW WE SEE THE PENCIL.

The inverted image of the picture on the retina is due to the shape of the lens. When the stimulus reaches the living cells of the retina and through them is passed on to the optic nerve and the brain, a series of changes takes place in these living cells. There is no evidence as to how an inverted or upright picture passes through these living cells in the retina and brain. We do know that we have to learn the meaning of all stimuli. For example, a baby reaches for things far beyond the length of its arms and it is only after many trials that it eventually acquires precision in reaching for an object. It is probable that each one of us passed through a similar stage of learning to interpret the stimuli that arose from light. In coming to understand light stimuli, the sense of touch was of great assistance. Try to explain how this would be so.

Care of Eyes. — The eye is our most important source of information; through it we learn to recognize each other and understand the appearance of our work. Just as soon as we realize that we do not see as readily as our companions, we should have our eyes examined, to be sure that there are no defects of vision. People with defective vision usually fall into three classes: first, those who can see objects near at hand, but do not recognize objects at a distance; such persons are near-sighted. Second, there are those who recognize distant objects but do not see clearly objects close at hand; such persons are far-sighted. These defects are due to the shape of the eye and can be corrected only by the use of glasses, which should be worn after a careful examination by a qualified physician. The third class consists of those to whom objects appear hazy. They are said to have *astigmatism*, which can be readily corrected by the proper glasses. This common defect is found when we compare the two eyes. We see better with one eye than the other. This is another defect that can be corrected only by the use of glasses. There are people who do not distinguish readily the different colors. They are color-blind. This defect cannot be corrected by the use of glasses.

In reading, the light should be sufficient and steady and should come over the shoulder. The eyes, like the rest of the body, get tired and need to be rested. They give us our best service when the entire body is in a healthy condition.

Cigarettes and Eyes. — When cigarettes are burned several poisons are produced. Nicotine, carbon monoxide, hydrocyanic acid, puridine, sulphureted hydrogen, picolin, and lulidin are some of the toxins that have already been isolated from tobacco. These poisons are absorbed in small quantities by the mucous membrane which lines the nasal passages and in large quantities when the smoke is inhaled in the lungs. Many persons, even adults, are made ill whenever

they absorb these poisons, and any competent physician can detect the detrimental effect of smoking on young people.

Some very recent investigations [1] on the influence of smoking on the eye prove conclusively that the poisonous effects are more marked and serious than the earlier studies revealed. Inflammation of the optic nerve, which seems to act on certain nerve fibers only, is thus produced. This causes a defect in the central field of vision first for green, then for red, and finally for blue and white. There is also an alteration in the size of the "blind spot" in some smokers. When these symptoms appear they can be relieved only by completely ceasing to use tobacco. If the person who is subject to tobacco toxemia does not abstain, then permanent blindness may follow. Since this habit of smoking has been taken up by girls and women who do not seem to have the resistance to these poisons that most men have, these toxic signs develop frequently within a few months after the use of tobacco.

271. The Ear. — The ear is a sense organ for the reception of the stimuli which we interpret as sounds. The ear of man consists of the outer, middle, and inner ear. The first two carry the stimuli to the third, where they are received by nerve cells and carried to the brain.

The diagram of the ear (Figure 254) shows the several parts and their relations. The outer ear leads to the *tympanic* (tĭm-păn′ĭk) cavity; the middle ear is in communication with the mouth, and the complex inner ear is partly shown. There is a group of small bones in the middle ear which conduct the sound vibrations to the delicate inner ear. The internal ear receives the various sound waves, and transmits them to the brain, where they are explained as sounds.[2]

[1] We are indebted to Dr. David F. Gillette, Syracuse, N.Y., for these recent facts concerning the influence of smoking on vision.

[2] When certain parts of the ear (semicircular canals) are injured, one has difficulty in standing or in walking erectly. This is because the inner ear serves both as a hearing and a balancing organ.

Hearing. — Sound waves strike the ear drum (tympanic membrane), which in turn causes the small bones in the middle ear to vibrate. The bones cause the water in the internal ear to move, thus stimulating the nerves of hearing.

The pressure of air on each side of the ear drum is normally the same. This is due to the entrance into the middle ear of air from the mouth, through the eustachian tube.

FIGURE 254. — PLAN OF EAR.

O.E, outer ear; *M.E*, middle ear; *I.E*, inner ear; *Eu*, eustachian tube.

This tube is a trifle more than an inch long. When it becomes closed, partial deafness results.

Defects in hearing may be caused by blows upon the ears, by the accumulation of wax in the ears, and by sore throat. When there is a continued ringing or hissing sound in the ears, consult a doctor at once.

Care of the Ears. — Next to our eyes the ears are our best sense organs, and we should know how to take care of them. There are so many harmful things that can be done and done so easily that one authority has said that the best treatment

to give the ear is " absent treatment." He means to let the ear alone except to keep it clean. To do this, the proper use of a wash cloth is all that is necessary. The wax in the ear normally moves outward and the cloth on the end of the finger will keep the ear sufficiently clean.

It is important to heed the old saying, " Never pick your ear with anything smaller than your elbow." Digging the ear with toothpicks, hairpins, and other hard and pointed instruments is often the cause of irritation that is followed by inflammation. If your ears are not acting right, go to an ear specialist.

Most of our ear trouble comes from infection in the middle ear, which is connected with the mouth by the eustachian tube. When one has a cold and blows his nose very hard, especially pinching the nose, the result is often to force some of the germ-laden mucus up the eustachian tube. Here the germs grow rapidly, causing a congestion and inflammation. The different conditions that arise from such infections of the middle ear are the chief causes of deafness.

The ear drum receives the gentle sound waves and transmits them through the bones of the middle ear to the internal ear. If the ear drum is injured, as it can be even by striking the ear with one's hand, it does not vibrate properly.

Special attention should be paid to getting proper rest and relaxation, and the eyes and ears should have particular care. In looking after these and the other sense organs, we should avoid the use of alcohol and tobacco, as these both have an injurious effect on the nervous system.

OUTLINE

Nervous system
- Nerve cells (neurons)
  - Cytoplasm
  - Nucleus
  - Fibers

Location of nerves
- Central system
  - Brain
  - Spinal cord
- Sympathetic system
  - Ganglia

- Growth of nervous system
  - Cells
  - Fibers
- Reflex action
  - Afferent
    - Sensory
  - Efferent
    - Motor
- Rest and relaxation
  - Fatigue toxins
  - Amount of sleep
- Brain efficiency
  - Effect of alcohol
    - Shrinking nucleus
    - Hurting Nissl bodies
      - Swelling cell
- Sense organs
  - Smell and taste
  - Seeing
    - Eye
      - Cornea
      - Sclera
      - Choroid
      - Lens
      - Iris
      - Pupil
      - Aqueous humor
      - Optic nerve
    - Care of eye
      - Nearsighted
      - Farsighted
      - Astigmatic
      - Color-blind
      - Harm done by cigarettes
  - Hearing
    - Ear
      - Outer
        - Ear drum
      - Middle
        - Eustachian tube
      - Inner
    - Care of ears
      - Cleanliness
      - Congestion

SUMMARY

The nervous system of all vertebrates consists of a brain and spinal cord with nerves passing to all organs of the body. The brain of man is the most highly developed.

All our movements are controlled by means of the nervous system. Through our sense organs we gain our information of the world.

The nervous system is made up of cells which are highly specialized. Their main work is to transmit and interpret stimuli. The nerves of man are so highly specialized that all stimuli which affect the eye are thought by us to be light stimuli; or all stimuli which enter the ear, seem to be sounds. The stimulus which passes over any of our special sense organs travels over several different nerve cells before it reaches the place in the brain where it is interpreted. The highly specialized nervous system and sense organs grow and are fed just as muscles or skin grow and are fed. There is no special food which we can eat that is used exclusively by the nervous system. When the brain is affected by alcohol, it is the highly developed centers that suffer most.

QUESTIONS

What is the nervous system? Of what parts is it composed? What animals have you studied that have a nervous system? Which ones lack a special nervous system? How does the nervous system grow? Describe the nerve cell. How does it differ from other cells in man? What are special senses? What kind of information do you receive through your eyes? What kind through your ears? Which do you remember? (The well-trained mind remembers equally well the information that comes in through each of its sense organs.)

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CHAPTER XXIV

BACTERIA: THE SMALLEST PLANTS

Why has not man a microscopic eye?
For this plain reason: man is not a fly.
Say, what the use, were finer optics given,
T' inspect a mite, not comprehend a heaven.
— POPE

272. Bacteria. — Bacteria are the smallest of all plants — so small that they can be seen singly only through the aid of a powerful microscope. We do not know all about their life processes, but we have learned much about their effect. We constantly hear about these plants, either under their correct name, *bacteria*, or under the names of *germs* or *microbes*. Two incorrect ideas concerning bacteria are prevalent, — one, that bacteria are animals, and the other, that all are harmful. It is definitely known that bacteria are plants; that small as they are, they are among the most important plants in the world; that most of them are helpful, and only a few harmful. They are, however, so much like the one-celled animals (protozoa) that the word *germ* is not unnaturally used to cover both.

273. Shape and Size of Bacteria. — Bacteria, according to their shape, are grouped into three classes: (1) round (the cocci); (2) rod-shaped, like a short unsharpened pencil (the bacilli); (3) those that are shaped like a corkscrew (the spirilla). Most of the names for the different bacteria contain one or another of these words, thus indicating the

shape of the bacterium[1] under discussion. The spirilla and the bacilli often have on one or both ends tiny thread-like hairs called *flagella* by which they move, giving the first observers reason to think that they were animals.

To show how small bacteria are, fifteen hundred of the rod-shaped form will hardly reach across the head of a pin. When bacteria are grown in the proper kind of substance, there are so many in a cluster that they appear as tiny spots or points, often tinged with a faint color. When seen alone under the microscope, they are clear, almost transparent, and colorless, and often have a bright, shining spot on the inside.

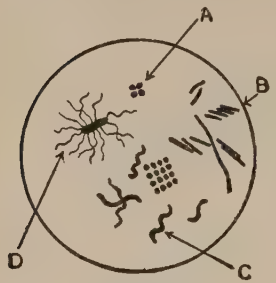


FIGURE 255.

A, cocci; *B*, bacilli; *C*, spirilla; *D*, bacillus with flagella.

274. Where Bacteria Are Found. — Bacteria are everywhere, — in the air, as invisible dust; in the upper layers of the soil; and in water. We breathe in the microbes of the air with every breath, but generally with no injurious result. Every bacterium has its own work to do, and a healthy body gives little opportunity for most kinds of bacteria to do harm.

275. Conditions Necessary for the Growth of Bacteria. — Like all other plants, bacteria must have all the proper conditions before they can grow and multiply. Their food is chiefly plant or animal matter, but they cannot make use of food except in the presence of warmth and moisture, and most of them require oxygen in addition. They get the oxygen from the surrounding air.

276. Life Processes. — In the preparation of their food bacteria break up organic substances, that is, decompose them, causing the condition known as decay. They use

[1] Bacterium, singular of bacteria.

some of the material resulting from decay; some they set free in the air; and the remainder is left on the earth to be used by more complex plants. In changing dead matter — plants, leaves, and animals — to a form which again becomes a part of the earth, bacteria perform a service valuable to man.

Reproduction occurs in bacteria through simple fission. Sometimes bacteria break entirely apart, while in other cases they remain connected, forming a chain. Under favorable conditions each cell can grow to full size in half an hour and be ready to divide again. It is this ability to multiply rapidly which makes them of so great importance, for a few hundred bacteria, even of the harmful ones, could produce little effect.

In the process of growth, bacteria produce two substances, *enzyme* (see page 28) and *toxin* (tŏx'ĭn: Greek, *toxicon*, poison). Enzymes produce fermentation, a breaking-up process of which man makes use to secure certain flavors and odors, as well as to soften hard materials. Toxins are usually poisonous to living organisms, including the bacteria which produce them.

Enzymes cause the pleasant flavor of such articles of food as cheese and butter. The quality of tobacco depends largely upon the kind of bacteria which have been at work upon it. Such bacteria are classed as helpful, as are those which gather nitrogen for the plants of the bean family. Other helpful bacteria are those which make it possible for man to use sponges by ridding them of the soft, slimy substance with which they are filled when alive, as well as the bacteria which soften the useless parts of the flax plant so that the rest of it may be separated and made into linen.

When food, air, warmth, or moisture is not sufficient, bacteria cease to grow and go into a resting state. That is, they change their form, and surround themselves with a substance which protects the soft protoplasm from being

harmed by freezing, heating, or drying. The simple plants all do this, but the simpler the plant, the more easily does it resist. It is this ability to withstand unfavorable conditions and to resume growth when conditions change for the better that makes bacteria "such good friends and such bad foes." Our ability to control them is due largely to a knowledge of their habits.

LABORATORY STUDY OF BACTERIA

Prepare culture plates of agar-agar from the following formula:

Agar-agar Formula for 1000 c.c.

Agar-agar [1]	15 grams
Beef extract	3 grams
Peptone	10 grams
Salt	5 grams
Water	1000 grams

Boil material for the agar-agar formula; add sodium hydrate till the color of litmus paper is not changed; cool to about 56° C., and beat into this one whole egg, including the shell. Warm slowly to the boiling point and continue till the egg is firmly coagulated; then strain the clear medium through a cheesecloth on to moist cotton in a filter funnel.

Work rapidly. Cool, and then boil once more. Filter through cotton into test tubes. Each tube should not be more than a quarter full. Plug the tubes with cotton. Then sterilize this mixture in the test tubes by placing them upright in water and boiling twenty minutes on each of three successive days. Let part of the test tubes cool, in a slanting position, having the plugged end elevated half an inch. These are called slant agar tubes. When petri [2] cultures are needed, melt up a sterile agar tube and pour into a sterile petri dish.

1. To show that bacteria are present on one's hands: draw the fingers of the unwashed hand across the surface of the agar-agar in petri dish; cover and set away for four days at room temperature or two days at body temperature.

2. To show that fewer bacteria are present on freshly washed hands: draw the fingers of the washed hand across the surface of the agar-agar; cover and set away.

3. To show that bacteria lodge under the nails, place on culture plates scrapings from under finger nails, (1) before washing the hands, (2) after washing the hands.

[1] Secured at most drug stores.

[2] Flat, round dish with cover.

4. To show that heating milk reduces the number of active bacteria, sprinkle drops of milk and water mixture on agar-agar petri dish, (1) natural milk, (2) pasteurized, (3) boiled. (Use one tenth milk and nine tenths sterilized water.)

5. To show that bacteria change the medium in which they grow, note, besides the number, form, size, and color of the colonies, whether any change takes place in the agar-agar.

6. To show that bacteria grow best in the presence of warmth and moisture, compare those grown under such conditions with those grown in a dry or a cold place. Note the influence (*a*) of warmth, (*b*) of cold, on the rapidity of growth.

7. To show that bacteria are in the air, expose the surface of the culture plate for a few seconds.

8. To show that flies distribute bacteria, let a fly walk across the surface of the agar-agar in the petri dish.

9. Expose a growing culture to strong heat; to strong sunlight.

10. Immerse a growing culture in 10% formalin, in 85% alcohol, or any other good germicides.

The term *germicide* usually refers to chemical germicides, of which the most common are corrosive sublimate, carbolic acid, chloride of lime, sulphur, and formalin. These are also antiseptics and disinfectants, and all of them are poisonous.

But germicide may also refer to the methods of destroying bacteria. A high temperature of 140 degrees if maintained for half of an hour kills the active bacteria, but those that are in the spore stage are killed only after prolonged heating. Moist heat is more effective than dry. Sunlight is one of the best germicides known. Bacteria cannot withstand the effect of direct sunlight for more than a few hours. The practical use of sunlight is limited because it requires that objects be fully exposed.

There are different forms of bacteria, such as soil bacteria, dairy bacteria, and the various bacteria whose growth is counteracted when food is preserved by canning, salting, and so on. These will now be taken up in order.

277. Soil Bacteria. — The surface soil, especially if it is rich in organic matter, contains many kinds of bacteria.

The bacteria decrease in number as you go deeper below the surface. At a depth of ten feet they are usually scarce. Ordinary earth may yield from 10,000 to 100,000,000 per gram if it has become polluted. Soils which have not been cultivated have fewer. The condition which really determines how many bacteria will be found in the soil is the amount of organic matter.

The soil bacteria do a most important work in breaking down the parts of dead plants and animals and in enriching the soil so that living plants can find more nourishment in it.

The roots of such plants as the clover and the pea (leguminous plants) become infested with certain bacteria found in the soil. These bacteria form bunches or nodules on the roots in which they live. Thus protected, they gather nitrogen from the air, use what they need, and store up the rest. This surplus is used by leguminous plants in making protein, part of which is found in the body of the plant, and part in the seeds. When the seeds are used as food, man and the animals secure the protein which they need. When the plants die, they leave the soil richer in nitrogen in a form that can be used by plants which do not have the help of the bacteria to gather it. So valuable is this form of fertilizer, that in some cases leguminous crops are raised and plowed under for the sake of the nitrogen in them, this being called "green manuring," a practice which was carried on for a long time before the reason for its value was learned.

The relation which exists between the plants which profit by the work of the nitrogen-gathering bacteria and at the same time furnish them protection is an illustration of *symbiosis* (sym-bī-ō′sis: Greek, *syn*, together; *bios*, life), the relation of mutual helpfulness between organisms of different kinds.

Inoculation. — Nitrogen-gathering bacteria are likely to be present in all soils in small numbers, but in order to have them help plants to an appreciable degree, there must be

many of them. It has been found possible to place them in the soil artificially, a process called inoculation. This is done either by wetting the seeds with water containing the bacteria, or by putting them into the soil in some other manner. Care should be taken to secure only pure cultures and to have them fresh. By the use of cultures a soil properly inoculated will not only produce larger crops of leguminous plants, but its quality is also improved for crops which follow them, as explained above.

Photograph by R. S. Breed.

FIGURE 256. — CULTURE DISH WITH BACTERIA (a).

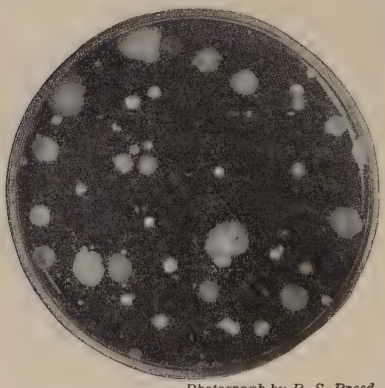
This culture was made from milk six hours old that had been kept in a refrigerator in a clean milk bottle.

278. Bacteria in Relation to Milk. — Milk as it comes from the healthy cow is practically free from bacteria of any kind. The number of bacteria present, however, is not of so much importance as the kind. But if a large number of bacteria are allowed to get into the milk, some of them are sure to be harmful and may find conditions so favorable for their growth as to make trouble for the person using the milk.

A high grade of milk will not contain more than 500 to 1000 bacteria per cubic centimeter. Such milk has been well cared for and comes from healthy cows. Some cities permit milk to be sold that contains as many as 100 000 bacteria per cubic centimeter and some even more. Such milk comes from unhealthy cows or dirty barns, or has been kept too long, or has " changed hands " too many times. To deliver pure milk to the consumer costs the producer

time, care, and money, and consumers should be willing to pay more for milk which has had proper care.

Keeping Milk Sweet. Ice prevents harmful bacteria from multiplying sufficiently to make milk dangerous, unless the milk is kept too long a time. Preservatives, soda, borax, boric acid, formaldehyde, and the like, are sometimes used to prevent the growth of bacteria. In some cases no immediate harm seems to come to the persons using milk thus preserved, but some of these substances are poisonous, and pure milk, properly cared for, does not need them. The use of any milk in which preservatives are found should be avoided.



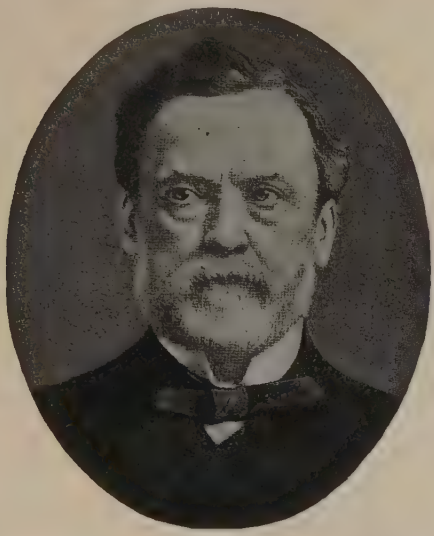
Photograph by R. S. Breed.

FIGURE 257. — CULTURE DISH WITH BACTERIA (b).

This culture contains the same amount of milk as that shown in Figure 256. It was taken from the same bottle six hours later after it had stood in a warm place.

Pasteurization. — A harmless bacterium gets into milk kept too long and forms lactic acid, thus giving the milk a sour taste and causing it to curdle. Sour milk is perfectly wholesome for food, but the taste is disagreeable. In 1857 Pasteur discovered this bacterium. He also found that milk could be kept for several days without becoming sour, after it had been heated sufficiently to kill this bacterium.

This process, called after its discoverer *pasteurization*, consists in heating milk for twenty minutes at a temperature of 60° C., or to a higher degree for a shorter time, and then cooling it rapidly. This procedure kills nearly all the bacteria in the milk and does not change the taste or make it



Louis Pasteur (1822–1895). This distinguished Frenchman was trained as a chemist and made a notable contribution to this field of knowledge before he began to study germs. Soon after the invention of the microscope, germs were found in water and the theory of spontaneous generation of life aroused new interest. Pasteur made a thorough examination of this problem and showed that no spontaneous origin of life took place when the germs were excluded.

Pasteur attained to his greatest success in his study of microscopic organisms, the "infinitely little," as he loved to call them. His first success was in the study of fermentation and diseases of wines. This was followed by his investigation of the silkworm plague. He then began the study of the prevention of disease, making a repeated series of pure cultures which rendered the germ less poisonous. This weakened germ he injected into animals to protect them from disease. He first tried this experiment on fowl cholera; then splenic fever; and after many years of experimentation he was successful in preventing hydrophobia in a human being that had been bitten by a mad dog.

The Pasteur Institute was established in 1888, an event of great scientific importance. More than thirty similar institutes have since been established in different parts of the world on the plans that he formulated. Pasteur probably made more important discoveries which were directly beneficial to human welfare and health than any other man.

hard to digest. Milk is not rendered absolutely sterile, but it is a much safer food, especially for infants. At best pasteurization is only a corrective or precautionary measure, and we should demand that milk be kept clean and thus free from bacteria.

Milk Products. — Most raw milk products have their own forms of bacteria, nearly all of which are helpful. The flavor of June butter is imparted by a bacterium different from the one in January butter. So with cheese, each brand or flavor receives its taste through the action of a special bacterium. At every step in the use and manufacture of milk, it is necessary to know the conditions under which the helpful bacteria work best, and how to keep out the harmful ones.

FIGURE 258.
The metal cap keeps out dirt which can get by the paper stopper.

Sources of Danger in Milk. — The cow herself may be unhealthy and her disease transmitted through the milk. Of the several diseases which this animal may give, tuberculosis is the most common. Children are more liable than adults to take the disease in this way. There is no necessity to be in doubt about a cow's being infected with tuberculosis, for in 1890 Koch discovered the tuberculin test, which enables the dairyman to detect the disease. This test is now commonly applied, and in some cities owners of herds which have been tested and found free from disease are allowed to sell their milk as " certified," though the meaning

of this term varies. Not only is the raw milk from tubercular cows dangerous, but also the butter and cheese made from it.

Bacteria multiply rapidly and remain active while milk is warm, consequently it should be cooled as soon as possible after it has been taken from the cow. Milk should not be used when it is too old, for in that case the harmless bacteria may all have died and harmful ones taken their places. Milk should not be left in a metal container, or open to the air, or placed in an ice chamber where it can absorb the odors of other foods.

Ice cream should be eaten only when fresh, for poisons (ptomaines) are formed by the action of bacteria, especially in ice cream which has been melted and then refrozen. Ice cream should be made under clean and healthful conditions, and should never be exposed to the air of the street.

279. The Preservation of Food. — The care of food is necessary to our health, for some of the germs which live and grow in food cause disease when taken into our bodies. After studying the habits of the different kinds of bacteria and knowing just what conditions are necessary for their growth, we can modify these conditions sufficiently to prevent the bacteria from growing or to kill them.

Our aim in preserving food is to keep it from "spoiling." We say that food is spoiled or unfit for eating as soon as the processes of decay have begun. It is important to keep in mind that decay or putrefaction *is always due to the growth of bacteria and similar organisms.* Any device which will check the activity of bacterial growth will delay spoiling. The problem of keeping our food free from decay becomes increasingly difficult with the increase in population. The following are some of the methods used in preserving food:

(*a*) *Canning.* — Canning is a simple plan of keeping bacteria away from food products. The food is not treated by any chemicals to prevent the growth of bacteria, but reliance

is placed entirely upon devices for keeping all bacteria from it. If this can be done, the food will not be subject to their action and will never spoil.

The process involves, first, removing the bacteria already present in the food; and second, preventing all other bacteria from gaining access later to the food. The first need is met by heating the food to a sufficiently high temperature to destroy the bacteria; while the second is met by hermetically sealing the food in a can or jar while it is still hot.

(*b*) *Preservatives.* — Preservatives are of two kinds, poisonous and non-poisonous. The non-poisonous preservatives are sugar, salt, vinegar, and spices. The use of such preservatives is perfectly proper and their success in keeping bacteria from growing is due to the fact that bacteria do not grow in solutions containing these substances. Fresh fish are preserved by rubbing with sugar. Condensed milk contains 30% to 40% of cane sugar. Jellies are preserved from bacterial action by the large amount of sugar which they contain. Raisins, figs, and dates are preserved partly by drying and partly by the presence of sugar. These three fruits contain so much sugar that it is not necessary to add sugar while drying. In recent years housewives have been preserving fruit, especially berries, by taking equal parts of sugar and fruit and then sealing up the can without heat. The large amount of sugar prevents the bacteria from growing.

Salt is one of the commonest and least harmful of preservatives and is used in a variety of products of which fat pork, corned beef, hams, and fish, are the most common.

Vinegar is another material that is a well-known preservative; the various kinds of pickles and olives are usually thus protected.

Many kinds of spices are in common use. These are more or less useful in protecting our food. This is well illustrated in mince-meat, which is a watery mixture of meat and fruit which under ordinary circumstances would readily putrefy.

The spices give the needed protection and when they are omitted, the mixture soon decays. The same principle is applied in preserving sausage meat.

All bacteria require a considerable amount of moisture for their life processes and cannot develop in moderately dry food. Nature has adopted this method of preserving the seeds of most plants. We find that the ripened seeds of grasses, wheat, corn and many other plants are dry. Flour is good food for bacteria only when it is moistened. The large amount of baked goods on the market to-day are protected largely because they are dry. Just as soon as bread is placed in water or moistened, it begins to decay. In the past few years a whole new industry has grown up around this principle of drying, with dried milk as one of the best examples.

Finally there is the use of low temperatures, such as cold storage refrigerators or even freezing. Bacteria cannot grow at extremely low temperatures and the food can be preserved indefinitely. However, this method does not destroy the bacteria that are in the food. It simply checks their growth.

280. Men Who Made the Study of Bacteria Possible. — The inventor of the microscope should be placed at the head of the list of men who made the study of bacteria possible, for without this instrument we should not know that such plants exist. We do not know who the actual inventor was, but the microscope was little more than a toy until it was improved by a Dutch naturalist, Leeuwenhoek (Lŭ′-wĕn-hook), in the latter part of the seventeenth century. Next in the study of bacteria comes Pasteur, who discovered and studied them in their relation to the souring of milk and in other fermentations. Then comes Koch, who discovered a way of separating bacteria so that each kind may be studied by itself, a method called getting a "pure culture." He also invented the tuberculin test. Most of our facts about bacteria have been secured during the past

thirty-five years, since men have learned how to prepare them for study.

281. Healthy Bodies and Bacteria. — So much has been said about harmful bacteria that a word of caution is needed. Two facts should make us take a sane view of the situation: (1) for every harmful bacterium there are thousands of helpful ones; and (2) harmful ones cannot do their work, or even live, in a perfectly healthy body, for such a body is constantly preparing a substance (antitoxin) which neutralizes the bacterial poison (toxin). Our chief aim, then, should be to keep well, and a few simple rules of hygiene will accomplish this. (1) Spend as much time as possible exercising in the open air. (2) Sleep as many as eight hours out of twenty-four in a well-ventilated room or out of doors. (3) Eat only food which agrees with you, and not too much of that. (4) Wear seasonable clothing. (5) Keep the skin clean through frequent bathing. (6) Have a definite occupation, work faithfully at it, do your best, and don't worry.

OUTLINE

- Bacteria
  - Size
  - Shape
    - Round (cocci)
    - Rod-shaped (bacilli)
    - Corkscrew-shaped (spirilla)
  - Where found
  - Conditions of growth
  - Life processes
    - Reproduction
      - Fission
    - Production
      - Enzymes
      - Toxins
  - Germicides
  - Soil bacteria
    - Symbiosis
    - Inoculation
  - Bacteria and milk
    - Pasteurization
    - Milk products
    - Danger in milk
      - Tuberculosis
  - Preservation of food
    - Decay
      - Due to bacteria
    - Canning
    - Preservatives
      - Sugar
      - Salt
      - Vinegar
      - Spices
    - Drying
    - Freezing
  - Bacteriologists
    - Pasteur
    - Koch
  - Healthy bodies and bacteria

SUMMARY

The smallest and simplest of all the plants are the bacteria. Most of them are helpful, ridding the earth of waste material, giving flavor to food, gathering nitrogen from the air for plants. Some bacteria are harmful and cause diseases in plants and animals. Bacteria are spherical, spiral, or rod-shaped. They are found everywhere, unless special pains have been taken to remove them. If they have plenty of food, air, moisture, and warmth, they multiply rapidly, and they go into the resting state, in which they can remain for a long time if any or all of the necessary conditions of growth are lacking. The harmful bacteria during their growth secrete a poisonous substance, toxin. When there are enough bacteria present to make a large quantity of toxin, the animal or plant host is made ill. Some bacteria, especially in the resting state, can bear freezing or boiling without being killed. In order to make anything "keep," it is necessary either to kill all the bacteria by making the substance sterile or aseptic, or to put into it a preservative, a substance in which the bacteria cannot grow. We should use great care to avoid the bacteria known to produce disease.

Milk, one of the most important articles of food, is a possible source of danger from harmful bacteria, which may get into it in various ways. Milk should be kept cold, and should be used before it is too old. The harmless bacteria in milk form lactic acid and cause the milk to sour. The growth of these bacteria can be checked by pasteurizing the milk. Ice cream, if too old, is dangerous, for the slow-growing bacteria have had a chance to develop.

The men who did the most to make the study of bacteria possible were Leeuwenhoek, who improved the microscope; Pasteur, who discovered bacteria in milk, and Koch, who found the way to make a pure culture and to test cows for tuberculosis. Many students are devoting their lives to the study of the various bacteria.

Every one should know the main facts about bacteria so that he may not have a foolish fear of them, but may be able to take reasonable precautions against the harmful kinds. Since a healthy body is the best safeguard against harmful bacteria, we should observe the laws of hygiene in order to keep well, and at the same time avoid, when possible, the bacteria which produce disease.

QUESTIONS

What are the main points of likeness between a bacterium and a flowering plant? How can food be protected from harmful bacteria? In what respects are bacteria harmful to milk? In what respects helpful?

Why are a few harmful bacteria not injurious in a healthy body? If one bacterium divides every half hour, and all live, how many will there be at the end of twenty-four hours? (Solve by arithmetic or by algebra.) Why does an apple with a broken skin decay more rapidly than one in which the skin is not broken? Why should one not put ice into water to cool it?

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CHAPTER XXV

HEALTH

Ah, what avail the largest gifts of Heaven,
When drooping health and spirits go amiss?
How tasteless then whatever can be given!
Health is the vital principle of bliss,
And exercise of health.

— THOMSON

282. Importance of Health. — The National Health Council estimates that the total loss in the United States annually from preventable diseases is $3,000,000,000. Under ordinary conditions about three per cent of the people are sick. While some of this sickness is due to diseases over which we have no control as yet, much of it is caused by parasitic animals and plants living in our bodies. Such diseases can be prevented by vigilance, cleanliness, and wholesome living, — in short, by *sanitation*.

283. Kinds of Disease. — While there are many causes of disease, all of them may be grouped under four headings: (1) Inherited diseases, *i.e.* those transmitted from parent to child, as certain forms of insanity and imbecility. (2) Diseases caused by such poisons as lead, arsenic, mercury, phosphorus, opium, cocain, alcohol, and the like. The disturbances which these chemical agents set up in animal tissues are easily recognized by a good physician. (3) Diseases which cause certain tissues to take on an abnormal growth, as in tumors and cancers. (4) Diseases caused directly or indirectly by some definite living plant or animal. Such diseases are called "biological diseases," because the source or cause is in all instances some definite living plant

or animal. In our ordinary daily speech we often speak of such ills as " germ " diseases.

Errors in Diet: Indigestion. — Besides these various diseases, there are many other ailments, of which the commonest is perhaps indigestion. This is sometimes due to errors in diet or to careless chewing, but there are other causes. It often happens that we eat too much or are too

FIGURE 259. — TUBERCULOSIS CURE, SUMMER.

tired when we eat. The fatigue that comes from overworking is sufficient at times to hinder the normal digestive changes. The same result may follow anxiety or worry. Sudden fright may check the flow of gastric juice and thus prevent the digestive changes. If the cause of such interruptions in the normal process of digestion is not removed, we become ill. So we see that unless food is digested, it cannot be absorbed. If it remains in the alimentary canal undigested, the bacteria which are normally present in the intestine begin to feed on it and decay sets in.

284. Biological Diseases. — The rattlesnake secretes a poison which is forced through fangs or hollow teeth into the blood of its prey. This poison affects the heart and may result in death. One of the common and beautiful mushrooms produces a similar poison which is not destroyed by cooking. If this particular mushroom is eaten, death is almost certain to follow in from twenty-four to forty-eight hours. In both these cases the animal or plant is large enough to be seen and easily recognized.

But there are a considerable number of microscopic plants and a few microscopic animals that have formed the habit of living for at least a part of their life in other plants and animals. During this time, as we have seen in the study of animal and plant parasites, they usually secure all, or the greater part, of their food from the plant or animal in which they are living. Two general causes of disease result from this parasitic habit. The parasite may destroy certain cells of the body, or the material thrown off from the body of the parasite may act as a specific poison.

285. Communicable Diseases. — The term *communicable disease*[1] is used in this book to mean the diseases caused by a plant or animal living as a parasite in plants, animals, or man. These diseases are communicated in various ways from one individual to another, from one animal to another, or from one plant to another.

The following are among the most common communicable diseases. Diseases caused by bacteria (minute plants) are tuberculosis, pneumonia, diphtheria, typhoid fever,

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[1] New York State designates the following as communicable diseases: anthrax; chickenpox; cholera, Asiatic; diphtheria (membranous croup); dysentery, amœbic and bacillary; epidemic cerebro-spinal meningitis; epidemic or streptococcus septic sore throat; German measles; glanders; measles; mumps; ophthalmia neonatorum; para-typhoid fever; plague; poliomyelitis, acute anterior (infantile) paralysis; puerperal septicæmia; rabies; scarlet fever; smallpox ; trachoma; tuberculosis; typhoid fever; typhus fever; whooping cough.

Professor Theobald Smith (1859, still living) is a technical scientist. Before any physician knew how to prevent disease, technical biologists had to discover how the disease germs live. Such is the work of Professor Smith, and he is an acknowledged authority in his field.

His best known discoveries are as follows: 1. He discovered that the protozoan parasite in the blood of cattle which causes Texas cattle fever is also found in ticks. It is carried from one cow to another by the infected ticks. This discovery led to similar discoveries in Malaria, Sleeping Sickness, and other protozoan diseases. 2. His scholarly researches in human tuberculosis have been of great value to mankind. 3. Present standards of meat inspection are based upon his investigations into the diseases of cattle and other food animals. 4. He was a pioneer in the manufacture and extensive public use of antitoxin.

bubonic plague, and whooping cough. Measles and scarlet fever are so similar to these in many ways that it is believed that they are caused by bacteria, although the definite bacteria which cause them have not been discovered. Diseases caused by protozoa (minute animals) are malaria, yellow fever, sleeping sickness, possibly smallpox, and others less well known.

FIGURE 260. — TUBERCULOSIS CURE, WINTER.

Manner of Infection. — The biological diseases are all preventable, especially the communicable diseases which result from the parasitic habit of some plant or animal. In order to prevent people from being infected with these diseases, it is necessary to know how the different plants and animals gain access to the human body and proceed to live there. This can be illustrated by describing pulmonary tuberculosis, a plant or bacterial disease; and malaria, an animal or protozoan disease.

286. Pulmonary Tuberculosis. — Pulmonary tuberculosis is a disease located in the lungs. The cause is a definite plant with parts and habits which are easily recognized by bacteriologists (students of bacteria). This plant is called *Bacillus tuberculosis*, and was proved to be the cause of consumption, or tuberculosis, by Robert Koch, a German scientist, in 1882. These tuberculosis bacteria, or germs,

Photographed by Henry Jones.

FIGURE 261. — BACILLI OF TUBERCULOSIS.

in countless numbers are found leading a parasitic life in the lungs of a tubercular patient. The bacteria are extremely minute, and can be seen only by the use of a microscope of high power.

The large number of germs in the lungs grow rapidly, and they are set free in the air by coughing. One tuberculosis patient may give off millions of these germs in a day. For this reason great care should be taken in destroy-

ing the sputum of patients, for if the germs become dry, they are carried about as dust particles.

Tuberculosis and other disease germs are so numerous that it is impossible to escape taking some of them into our bodies, but they usually do us no harm unless we are in a weakened condition.

Modern methods of cleaning the streets by flushing with water, keeping garbage covered, and wiping up the dust in our homes instead of using the old-fashioned feather duster are doing much to keep down the number of germs in the air which we breathe.

The bacteria that are breathed in from the air may find some weak place in the lungs in which to take up their parasitic lives. Those which enter on the food pass from the digestive tract into the blood and are eventually carried to the lungs. The introduction of tuberculosis germs in this way is especially frequent in children. In many cases milk from tuberculous cows is the source of the germs.

The cause of pulmonary tuberculosis is, then, the tubercle bacillus, which is taken into the lungs in the air we breathe, or through the food eaten, or by personal contact with a consumptive patient. These germs cause certain parts of the lungs to become diseased.

Getting Well. — Consumption is not necessarily fatal, especially if treated in its earliest stages. But many people who have the disease do not consult a regular physician until it has made considerable progress, and then it is too late to bring about a cure.

Figures 259 and 260 show the present method used in treating tuberculosis. The patients are given tissue-building food (protein) and are required to sit and sleep out-of-doors as much as possible. Rest, good food, and fresh air work wonders in arresting the progress of this disease.

When the body gains the requisite amount of strength the disease and its germs are usually thrown off. Patent

medicines and alcohol should be avoided, as they reduce the power of the body to resist disease and give no aid in building up the diseased tissues. In addition, alcohol causes serious disturbances in the general circulation.

In addition to pulmonary tuberculosis physicians recognize tuberculosis of the throat, intestines, kidneys, brain, and joints.

287. Influenza. — This is a communicable disease that killed more than 550,000 people in the United States during the fall of 1918 and the winter of 1919, which is about five times the number (111,179) of American soldiers officially stated to have lost their lives from all causes in the World War up to the date of April 30, 1919. This disease is contracted only by those who come in contact with the secretions from the nose or bronchial tubes of one who is affected with it. The word contagious is properly used for such diseases, because the person suffering from them gives off germs that pass to another. In this same sense tuberculosis, diphtheria, and typhoid fever are contagious diseases.

When the disease is of average severity the symptoms are a chilly sensation, headache, and " bone ache," or pains all over the body, and fever. Coughs usually develop as the progress of the inflammation extends into the bronchial tubes. The full force of this disease may center in the respiratory organs, or in the muscles and nerves, or in the digestive tract. It is clear that influenza paves the way for pneumonia, if it does not actually produce it.

The mouth and nasal passages should be kept clean with such washes as salt in water or borax in water in the proportion of one level teaspoonful to a pint of water. The chief value of all nasal washes is the water, and any preparation that has a smarting reaction should be avoided. There is really no special method of cleaning the nose that excels the natural method, *i.e.* blow it, and blow it into a paper napkin and burn the napkin.

This disease spreads in epidemic form about once in a generation throughout the earth along the routes of travel, and is carried from place to place by man. The name *Influenza* was given to it in Italy about one hundred years ago, because it was supposed to be due to the influence of some malevolent agent of the air. The French term "*La Grippe*" is given to this same disease; while the expression *Spanish Influenza* simply means that the 1918 epidemic started in Spain or was first noticed in epidemic form in Spain.

Home Report. — Look up the ravages of influenza in India, Alaska, etc.[1] See what you can find out about the total number of deaths in the different nations of the world.

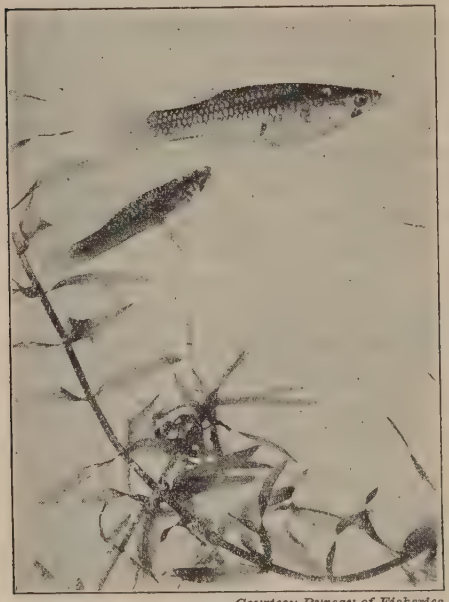
288. Malaria. A Protozoan Disease. — Malaria is a disease caused by a protozoan or minute animal which is distributed over the greater part of the world. The malaria protozoön is a minute simple cell of living matter. It resembles the amœba in its form and ability to change. This parasite penetrates into the red blood corpuscles and remains in them for twenty-four or forty-eight hours, or until the substance of the corpuscle is nearly used up. Then the parasite escapes into the plasma of the blood and later enters a fresh corpuscle.

Source of the Malarial Parasite. — The word malaria means *bad air*, for it was formerly believed that foul air caused the disease. When it was learned that a definite animal was the cause both in man and in other animals, the problem was to find how the parasite entered the body. It has been proved to the satisfaction of scientists that the malarial protozoön is injected into the blood by a particular kind of mosquito (Anopheles) which carries malaria germs in its body. (See page 83.)

The mosquito sucks the blood from a man or an animal

[1] Influenza Studies by Raymond Pearl. Reprint No. 548, Public Health Reports, Treasury Department.

suffering from malaria. This blood contains some of the malarial parasites, which pass into the stomach of the mosquito. They then migrate into the salivary glands of the mosquito, so that as soon as the mosquito bites another man or animal, it pours out some saliva which introduces the parasites into the victim's blood. While in the body of the mosquito, these parasites pass through definite stages in their life history; and when they reach the blood of man, the remaining stages are completed. Thus a man, or an animal, and a particular mosquito are necessary for the complete life history of the malarial parasite.



Courtesy Bureau of Fisheries.

FIGURE 262. — MOSQUITO-DESTROYING FISH.

This means in addition that for the prevention of malaria all that is necessary is to prevent the Anopheles mosquito from breeding, or in case this cannot be done, to screen adequately the houses, tents, and bedrooms in the regions where the mosquitoes live. It is interesting to note that the methods for the prevention of malaria were more than anything else responsible for the successful completion of the Panama Canal. The construction of this important work thus became a health as well as an engineering problem.

The cause and prevention of malaria is easily understood now that scientists have found out just how this protozoan animal lives. Each of us can protect himself from mosquito pests wherever we live. This blessing we can better appreciate when we study the importance of these animals in determining the history of ancient peoples. In ancient Egypt, for example, the natives in the marshy regions built towers in which to sleep because the mosquitoes did not fly so high. Records show that at least three kings were compelled to withdraw their troops when they were besieging ancient cities because of the prodigious number of "gnats." The history of Rome records periodic outbreaks of malaria, and the "deadly Campagna" was a marshy region that was more destructive than war to those who lived near it. It is not strange, then, that the Romans had a goddess of fever which they tried to propitiate.

As long as mosquitoes were regarded merely as pests, little effort was made to exterminate them, but as soon as it was discovered how destructive they are of human life, men everywhere began to study methods to eradicate them. In the numerous experiments that have been made to learn the true relation of mosquitoes to disease, men instead of animals have been used. Living mosquitoes which had bitten men with malaria were allowed to bite men who did not have this disease. These men then came down with malaria. In the same way yellow fever was proved to be caused by the mosquitoes technically known as *Aëdes* but formerly named *Stegomyia*.

The moral courage exhibited by these men is equal to the bravery of heroes in battle. This small group of less than a dozen men who permitted themselves to be experimented upon has saved thousands of lives and enabled man to make regions, formerly uninhabitable, places where mankind can live in safety and freedom from the fear of these diseases.

289. Quarantine.[1] — When a person or a group of persons is suffering from a communicable disease, or when any one has been exposed to the germs of any such disease, the Board of Health may place him under *quarantine.* The nature of the quarantine depends on the specific disease and the laws of the town or state in which the disease is prevalent.

The New York law[2] on this subject is typical of the best state laws on quarantine. It says:

"The Board of Health shall prohibit and prevent all intercourse and communication with or use of infected premises, places, and things; and require, and, if necessary, provide the means for the thorough purification and changing of the same before general intercourse with the same or use thereof shall be allowed."

This means if an individual is suffering from scarlet fever or diphtheria, or some other communicable disease, he shall not associate with the general public until he has ceased to be a source of infection. His liberty is temporarily restricted by quarantine because he may be the cause of sickness and even death to others by spreading the germs of communicable disease.

It is interesting to know that the more highly civilized a nation, state, or city becomes, the more specific and exacting are the quarantine regulations. There is every reason to believe that in the near future the present laws of quarantine will be extended. In addition to individuals being quarantined in a dwelling, all the inhabitants of a city or state may be quarantined in case of severe epidemics; or the transportation of stock from one state to another may be prohibited in the case of a serious communicable disease

[1] When practicable, it is well to have the local health officer discuss such subjects as disinfection and quarantine.

[2] The Sanitary Code of the Public Health Council of the State of New York defines the health officer's duties in detail and may be had by writing to the State Department of Health at Albany.

existing in cattle or sheep. The quarantine laws, for example, order from time to time that all dogs in the town or county shall be muzzled as a protective measure against rabies.

Immigrants suffering from certain diseases are prohibited from landing in the United States. This means that there are national as well as state and city quarantine laws. The present quarantine laws are the most effective protective measures against the spread of disease known to man and are the product of a high degree of civilization.

Violation of quarantine and of the various health regulations, such as the pollution of water and improper care of refuse and sewage, should be reported to the local health officer. In case no satisfactory results are obtained from the local health officer, the question may be referred to the State Board of Health, which gives prompt and efficient attention to all questions concerning the health of the people of the state.

290. The Worm Group. — The word " worm " is an old term which properly describes such animals as the earthworm, sea-worm, leech, tapeworm, flatworm, and a few

FIGURE 263. — FLATWORM.

others. The word " worm " cannot be correctly used for such larvæ of insects as the " apple tree worm " or " currant worm."

The worm group is divided into two classes: those whose body is composed of numerous *segments* (sĕg′mĕnts) or rings, such as the earthworm, and those whose body is not segmented, such as the tapeworm and flatworm. The first class comprises the true worms, which are known as *Annelida* (ă-nĕl′ĭ-da). The second class, the unsegmented worms,

have no single technical name, and are not believed by scientists to be true worms. They comprise a number of worm-like animals which have hardly any features in common. Here are found the fresh-water planarians, the parasitic tapeworms, liver flukes, hookworm, and numerous round worms, of which the hair worm is an example.

FIGURE 264. — HAIR WORM LIVING AS A PARASITE IN THE BODY OF THE GRASSHOPPER.

291. Tapeworm. — In their structure and habits tapeworms are all much alike. (See Figure 265.) A mature tapeworm consists of numerous segments, often many hundred. Its "head" is armed with hooks or suckers or both, by means of which it holds on to the wall of the intestine. The remainder of the body floats freely in the digestive fluids and absorbs such nourishment as the worm requires.

The segments at the free end of the body become ripe and drop off. The word *ripe* is used here to mean that the eggs have matured and are ready to give rise to more tapeworms. Each of these eggs, which has already begun to develop, is surrounded by a tough sac. This is as far as it can go in its growth unless it is eaten by another animal. The young tapeworms in their sac do not search for the animal that is necessary for their further growth and, unless accidently eaten, they die. As soon as the young tapeworm enters the

intestinal tract of the second animal (the second host), the tough sac is lost and the young worm begins to migrate into the tissues. In the tissues, it passes through more changes in growth but is still small and unlike its parent.

Here it must remain until finally discharged and eaten by an animal similar to the one from which the eggs escaped. As it enters the intestinal tract of the first host, the strange young worm transforms into a worm like the parent. A single adult tapeworm may discharge millions of eggs.

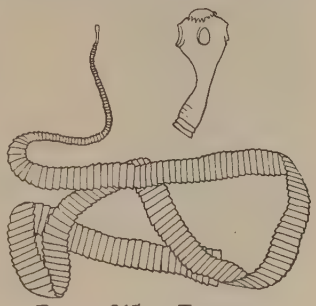


FIGURE 265. — TAPEWORM. Showing hooks in head.

Such parasitic worms injure the mucous membrane lining of the intestine, permitting the entrance of bacteria and sometimes causing ulcers. They absorb much food, usually causing a ravenous appetite, and may even have a poisonous effect.

Prevention is secured by abstaining from eating raw meat, which is the only source of infection for human beings. The commonest tapeworms found in man are the beef tapeworm and the pork tapeworm.

292. Trichina. — Another unsegmented worm that is of economic importance is the Trichina (trĭ-kī′na), now generally called Trichinella (trĭ′kī-nĕl′la). This worm lives in the intestine of mammals and from the intestine migrates into the muscles of its host. In the muscle it becomes encysted and remains until the flesh is eaten by some other mammal. When pork, infected with this parasite and insufficiently cooked, is eaten by man the cysts are dissolved by the digestive fluids and the worms are freed.

These worms then develop eggs and sperms, which after uniting mature into young worms and migrate through the intestine into the muscles. The activity of the worms at

this stage causes a serious inflammation of the tissues and a disease known as trichinosis (trĭk-ĭn-ō′sis), which is often fatal. Hogs contract trichinosis by eating refuse that contains the encysted worms.

Government inspectors examine pork which is to be exported or sold in large quantities to see that it is free from these parasites. The smaller sales of pork by local dealers are not inspected, and the only way to be sure of the harmlessness of the meat is to cook it thoroughly.

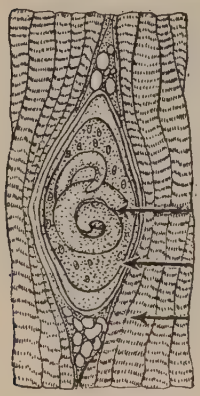


FIGURE 266. — TRICHINELLA.

A picture of this parasitic worm in the muscles of man. Note the membranous sac which incloses it. This is the form of the sac after the worm comes to rest in the muscles. The worm is then said to be encysted.

293. Hookworm Disease. — This disease is caused by a parasite which is classified as one of the worms. Hookworm disease belts the earth in a zone which extends thirty-three degrees each side of the equator. This disease is important because of its enervating effect upon the people suffering from it. It makes them incapable of work, and in the bodies of children results in a pitifully stunted growth. Great progress is being made in the United States in curing those suffering from this disease. The wearing of shoes and the use of a sanitary closet are usually sufficient preventives to protect the people who live in a hookworm district.

294. Immunity. — *Immunity* is a technical term which means that the body resists or is not susceptible to the germs of biological diseases. Many persons do not become sick when there is an epidemic of typhoid fever, measles, malaria,

or the like. Such persons are said to possess a high degree of *natural immunity* to disease germs. Healthy people will frequently take germ diseases when the body happens to be exhausted by care or work. In such cases the immunity of the body has been weakened. In contrast with natural immunity is *acquired immunity*. This is usually secured through the use of antitoxins (serum therapy), although many of the germ diseases confer immunity against a second attack of the same disease, but this does not hold true for all persons or for all germ diseases. Vaccination against smallpox, in the case of most persons, confers immunity for about seven years. Inoculation with the typhoid serum confers immunity for possibly two. Immunity, then, is a relative term, and depends in a large measure on the state of health of the individual and on his power of resisting the poisonous effects of disease germs.

STUDENT REPORT

Fill in the blanks below. In cases which you do not know about, consult medical books or the encyclopedia.

	Due to Some Plant or Animal		Treatment by			Prevented by				
	In the water	From contact	Nature	Medicine	Antitoxin	Personal care	Quarantine	Boiling the water	Fumigation	Killing flies
Cold										
Measles										
Whooping cough .										
Typhoid fever . .										
Tuberculosis . .										
Add others . . .										

295. Vaccination. — The success which has attended the efforts of man to overcome disease is well illustrated by

smallpox. For centuries this disease was responsible for many deaths throughout the world. It is said to have existed in China centuries before Christ. Later it swept over Europe again and again. A famous French physician wrote in 1754 that every tenth death was due to smallpox, and that one fourth of mankind was either killed by it or disfigured for life. Smallpox was brought into the Western Hemisphere soon after the discovery of America, and killed thousands of the Indians. It also affected the colonists. In 1721, Boston was ravaged for the sixth time by this disease. Out of the 10,567 inhabitants, 5989 had the disease and 894 died.

In 1796, Jenner, an Englishman, demonstrated the fact that by inoculation of a person with cowpox, a disease peculiar to cows and in some way allied to smallpox, the patient would become immune to the dreaded disease. This was one of the greatest and most beneficial discoveries about disease which has ever been made.

As the result of vaccination and sanitation smallpox has become a rare disease in the civilized nations of the world, and is least prevalent where the vaccination laws are the most stringent.

Vaccination for smallpox consists in the inoculation of the human patient with vaccine, a substance secured from a cow suffering from cowpox. This usually causes a slight illness, but during the illness the patient acquires a power which enables him to resist the germs of smallpox. This acquired power of resistance is called immunity. Immunity secured through vaccination or through having a disease, such as whooping cough for example, is described as *acquired immunity* to distinguish it from that form of immunity to all diseases or to certain diseases which many people possess. This latter is *natural immunity*. Those in the class who have not had measles may be said to have a natural immunity against measles. Those in the class who

have had measles once have an acquired immunity against measles.

Many people do not understand the theory of vaccination and its advantages, and have opposed its use through fear of acquiring lockjaw from the vaccine. It has been established that proper vaccine matter never contains the germs of lockjaw, and if this disease then occurs, it is due to failure in keeping the arm clean during the period when the vaccination scar is forming.

Immunity to disease is now being produced through inoculation. The patient is inoculated, that is, there is introduced into his circulatory system a virus, or serum. Each disease has its own virus, as the vaccine in smallpox, and this virus produces a mild form of the disease. This causes the cells to become resistant to the germs or microbes of the specific disease. Inoculation is being widely used for the prevention of typhoid fever. All soldiers are required to take this treatment. It would be desirable for all people to become immunized against this disease, but those who travel extensively and thus have to drink all kinds of water and milk should certainly undergo this treatment.

Vaccination and immunization reduce the liability of death in case the disease is acquired, but they do not absolutely prevent the disease. If a vaccinated or immunized person gets an overwhelming number of germs, he may have an infection of a slight kind. But the liability of contagion is reduced to a minimum.

296. Antitoxin. — We cannot say definitely why vaccination and immunization act as they do. It is known that if a poison (toxin) produced during a case of diphtheria is gradually introduced into the blood of a horse, a substance is produced which destroys the injurious effects of the diphtheria poison. The serum from the blood of the horse is called antitoxin, and may be preserved for use at any time to destroy the influence of the diphtheria poison. A given

amount of this antitoxin is introduced into the blood of the patient suffering from diphtheria, and usually counteracts the poison of the disease. This treatment has saved countless lives. It is estimated that in the ten years following the discovery of the diphtheria antitoxin the lives of a million children were saved in France alone. State boards of health usually furnish antitoxin for diphtheria and lockjaw.

297. Sanitation in the Home. — All of these wonderful discoveries about the cause and the prevention of disease fail to help us much unless we do our part. This we can do by first, becoming intelligent about the facts which scientists have discovered; and second, by applying proper sanitary measures in our homes. It is a fact that the health conditions in the country in recent years are not as satisfactory as those in our cities where stringent laws require the proper disposal of all wastes.

Our food must be protected from rats, mice, and flies, as each of these animals carries disease. The presence of any of these three animals about your home is an indication that there is plenty of exposed food for them. You cannot expect to have a clean home under such conditions.

The study of bacteria reveals that they are carried about on dust particles. It is a common experience that colds and influenza spread more rapidly when there are strong winds and no snow in late fall and early spring. These are conditions that we cannot control, but excessive amounts of dust in the cleaning of our homes may be prevented by using proper methods of sweeping and dusting.

We are coming more and more to use vacuum cleaners for all public places and there is no better method of removing dust from our homes. If a vacuum cleaner cannot be afforded, the room should be dusted with a damp cloth after it has been swept. In this case, it is necessary to wait until the dust has settled. Rugs and draperies hold a great deal of dust and should be taken out of doors and well

cleaned. Hard-wood floors are more hygienic than carpets because they can be cleaned more easily.

298. Disinfection and Disinfectants.[1] — The time when disinfectants shall be used and the manner of disinfection have been considered important factors in preventing the spread of communicable diseases. The purpose of disinfection is to destroy the germs lodging on clothes, floors, carpets, and curtains. People who care for the sick should know where the germs are likely to be and how to disinfect places where they have found lodgment. The term *disinfectant* is sometimes incorrectly applied to deodorizers, substances which are used to destroy odors, but the word should be applied only to substances which destroy germs or bacteria.

Disinfectants are not expensive, and few of the patented preparations are as satisfactory as the common ones used by boards of health. Weak solutions of carbolic acid and bichloride of mercury are chiefly used for killing the germs on the hands and clothing, or for cleaning the woodwork in the sick room. Chloride of lime is used to kill the germs in the discharges of the body, and sulphur dioxide and formaldehyde gas for the final killing of the germs in the room or the whole house before it is occupied again.

Never use any methods of disinfection unless they have been personally recommended to you by a physician or an expert in the details of room disinfection.

299. Antiseptic Lotions and Gargles. — This is a subject about which there is a difference of opinion. Let us examine the scientific facts involved and then see to what extent such preparations are beneficial. The germs which are causing a sore throat, for example, are living on the membrane which

[1] It takes five pounds of sulphur to disinfect a room which contains 1000 cubic feet of air. Three ounces of forty per cent formalin, to which is added two and one tenth ounces of potassium permanganate, will also disinfect the same sized room. Compare the cost and ease with which each is used.

lines this passage. The cells in this tissue are delicate and easily injured. In our study of bacteria, it was shown that only extreme poisons or prolonged heat was sufficient to kill them. Any poison that is powerful enough to kill the germs when used as a gargle will cause very serious injury to the cells in the tissues of the throat. When we use one of the many so-called antiseptic gargles, then, we do not kill the germs. What does happen?

These germs are washed free to some extent from the surface of the throat but not from the folds of the tissue as in the tonsils. Is there any remedial property to these gargles? In nearly all cases, there is not. What is the proper gargle to use? The one most employed now is salt and water. Such a gargle is cleansing and stimulating. These are the two important results to be obtained by a gargle.

The same principle applies to lotions which are used in the cases of bruises especially. None of the lotions have any more cleansing effect than soap and water. Camphor and witch hazel are old-time lotions that are still used. Both of them contain a large amount of alcohol. It is the alcohol that is the stimulating agent in these two lotions. It causes the skin capillaries to expand and thus permit the blood to flow more freely.

Any antiseptic which will actually kill the germs is really a disinfectant (already discussed on page 423).

300. Emergency Treatments. — We often have minor accidents to which we can give temporary care.

Cuts and Hemorrhages. In the case of serious bleeding, the skin will be broken and we already know that the wound must be kept as clean as possible. As a rule you will not have at your command sterile dressings, so it is better not to wash, touch, or put anything into a serious wound unless a doctor cannot be found.

The small veins and capillaries when injured do not cause serious bleeding or hemorrhages, but when the blood spurts

out or flows in a stream, then it is necessary to apply the tourniquet. This is a device which exerts a heavy pressure on the blood vessel and thus stops the bleeding. As it must be long enough to tie around a limb, a big handkerchief, towel, or wide bandage may be used. There must be a pad to make the pressure over the artery or vein greater than on the rest of the limb. The tourniquet must be put on tight enough to stop the bleeding and is rarely made too tight. Usually this should not be left on for more than an hour.

Bruises. The best cure for bruises is rest. Sometimes the application of a soothing lotion helps to relieve the pain, but only time can replace the injured cells.

Burns. The usual burns are accidents that injure the skin only. If the burn is deeper than this, it will require medical attention, and the best care that you can give is to do nothing. The smarting and burning sensation from superficial burns can be lessened by applying olive oil or a paste of baking soda. If the burn is kept free from dirt, it will readily heal without any special treatment.

Fractures. — In the case of fractures the injured part should be kept as quiet as possible. Any movement in the broken limb is likely to increase the difficulties of healing. The best treatment is to try to keep the part unmoved until a physician arrives. If it is necessary to move the injured person, a temporary splint should be applied. Anything that is stiff and rigid may be used, such as shingles, limbs of trees, umbrellas, or wire netting. In applying the splint, it must extend if possible beyond the joint below and the joint above the break in order to prevent movement in the broken parts. Such splints can be tied in place with handkerchiefs, strips of clothing, or bandages. Do not tie directly over the break. There must be an inner and outer splint when the break is in the arm or leg.

Poisons and Neutralizing Agents. — It occasionally happens that some one by accident takes poison, and it is im-

portant to know what to do until a physician can be secured. The first thing to do is to empty the stomach by an emetic. A glass of warm water with as much common salt as will dissolve in it or a teaspoonful of mustard in a large quantity of warm water will usually start vomiting. As soon as the stomach has been emptied, some neutralizing agent should be swallowed. In case an acid or corrosive sublimate has been swallowed, its action causes injury to the mucous membrane. Epsom salts, soap, or white of an egg followed by castor oil is beneficial. Young children may eat match-heads which contain phosphorous. This substance is also in some rat poisons. In this case use an emetic, preferably sulphate of copper, one to three grains in solution every ten minutes. After the patient has vomited use epsom salts, but no oil.

Prevention is the best neutralizing agent, and this can be accomplished by leaving nothing of a dangerous nature in easily accessible places.

301. Keeping Well. — The object in studying the preceding material in this chapter is to teach us to keep well. Our best doctors are spending much effort in showing how to avoid disease, for no one is benefited by illness. The old notion that children should be exposed to measles, scarlet fever, and whooping cough is wrong, for none of these childhood diseases is necessary. The time will come when our homes and surroundings will be so sanitary that the common diseases caused by germs will be eliminated, or at least decreased in number.

Government inspection of meats is lessening the amount of disease contracted from eating diseased pork, other meat, and fish. The United States Department of Agriculture is making every effort to inspect such products, and the department is fairly successful in inspecting the larger establishments. Many cattle and hogs, however, are killed and sold locally, and they escape inspection, so that buyers of this

meat have no protection against a general condition of disease.

Another danger to health is from the people known as " carriers " of disease, as such people give no evidences of illness. Typhoid and diphtheria are the two diseases most likely to be carried in this way. Many of these carriers serve as cooks, and as they give no evidence of being in other than perfect health, they often spread the germs through the food they prepare. If habits of absolute cleanliness are insisted upon, much of the danger of the dissemination of germs in this way may be removed.

Many hotels, public institutions, and well-run households insist that a prospective servant shall be examined by a competent physician before being engaged for work. In this way carriers may be detected, and persons with germ diseases, like tuberculosis, for instance, are prevented from spreading disease either in the food or in the air.

Children in the schools frequently have diphtheria germs living in their nasal passages or throats, but are not ill. After a time a number of children are stricken with the disease. A doctor then takes a sample of the contents of the throat and nose of each child. The bacteria in the mucus from the nasal passages are allowed to grow for twenty-four hours in a special preparation called a *culture*. At the end of that period the cultures are stained and examined with a high power microscope, and if diphtheria germs are present, they are easily seen. If one of the well children has these germs, he is treated until they disappear.

302. Save the Children. — The care which animals take in the protection of their young is one of the most fundamental instincts of their nature. But in civilized man his instinct is broadened and controlled by the power of reason and a knowledge of the laws of hygiene. Until man came to understand these laws, many of his efforts to protect his young were of no more avail than the brave fluttering and

plaintive cries of a bird when a red squirrel is robbing her nest.

During the last decade there has been an attempt to reduce the death rate among children. It is lower in America than in most countries of the world, and in this fact we take pride. The state of New York has the lowest death rate among children of any state in the world of which we have accurate knowledge. Yet there are communities in this state where the waste of infant life is a disgrace to civilization. The centers where this high death rate exists are largely populated by foreigners whom we permit to live in unhygienic conditions.

In a study of 9912 deaths among infants in New York State for the year 1916, over 55 per cent, we find, died from measles, whooping cough, bronchitis, pneumonia, bronchopneumonia, and infantile diarrhea. All of these are due in large part to parental ignorance concerning the elementary facts of sanitation and the proper care and feeding of infants. The infantile mortality among the foreign-born mothers is much greater than in the native white mothers. Particularly high death rates prevail among the Polish, German, and Austrian mothers.

It is difficult properly to measure the value of health to the community. When the wage earner is sick and is placed in quarantine, the loss of money is the amount he might have earned. In the case of a typhoid fever epidemic the total loss is many thousands of dollars. Further, there is no adequate measure of the sufferings of those who die and the heartaches of those who survive. But both the suffering and the financial loss can be greatly lessened by improving our sanitary laws and aiming at a better state of health for all the people. An increase in taxes to provide cleaner streets, public playgrounds, proper sewage disposal, and adequate inspection of milk, meat, and water, is really an economy. For although such improvements cost money,

they are not so expensive as epidemics of disease and the maintenance of hospitals and of orphan asylums.

303. Epidemics after Wars. — The return of two million men from Europe after living there for several months, to scatter throughout the United States, raised public health questions of great interest. After the Crimean War (1854–1856), cholera was epidemic in France and England; after the Franco-Prussian War (1870–1871), smallpox was epidemic in

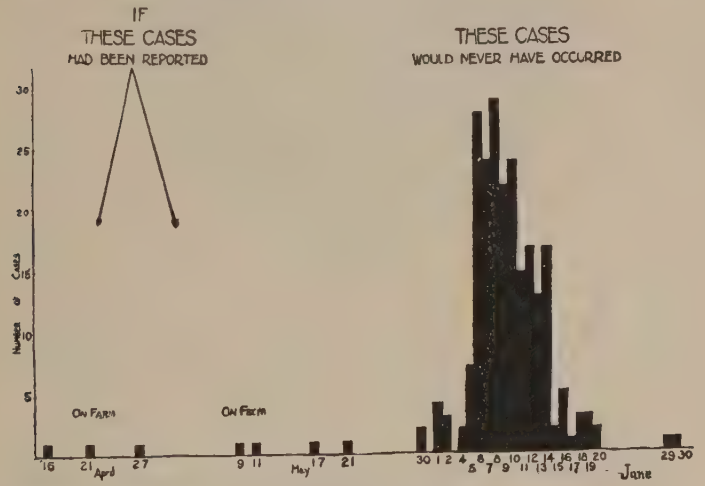


FIGURE 267. — STORY OF THE EPIDEMIC OF SEPTIC SORE THROAT AT ROCKVILLE CENTRE, LONG ISLAND.

England, Germany, and Austria; after the American Civil War (1860–1864), typhoid fever spread to many of the northern cities; and after the Spanish-American War (1902), typhoid and smallpox were very common. These historical facts show that there has been great danger in the past from returning troops.

The officials in the army and navy thoroughly understood the dangers and tried to take proper precautions against the spread of disease; but the task was very great.

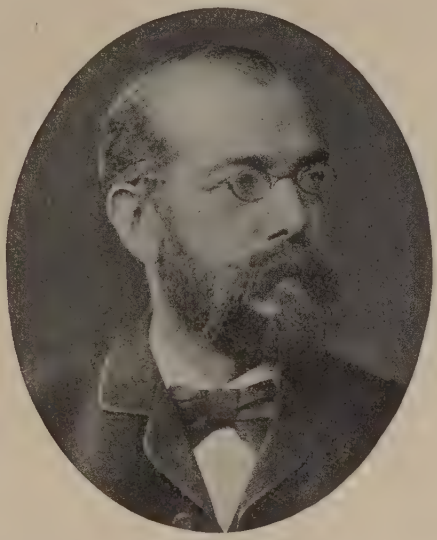
Some of the epidemic diseases in Europe were of the types which, once well started, might produce great havoc. They included trench fever, typhus, relapsing fever, cholera, and plague. Most of these are transmitted by vermin, most commonly the louse. In general the conditions are not favorable in the United States for the transmission of disease by lice, although in certain congested quarters they are common.

The term *epidemic* as used in this paragraph refers to the widespread occurrence of a disease in which a large number of people in a community are affected at the same time. This is the usual sense in which it is used by physicians.

All American troops were detained in Europe at foreign ports for two weeks, during which time they were deloused. After the troops had embarked, they were inspected a second time for lice. On landing in the United States, all the troops were sent to debarkation camps, where universal delousing was practiced.

Many people think that Americans take so many precautions and are so well trained in ordinary questions of personal and civil hygiene that epidemics are impossible. While many are familiar with the ordinary rules which science has devised for their protection, it is necessary for all to observe them. Those of us who understand the real meaning of communicable disease must take upon ourselves the responsibility of helping to explain the cause of all such disease to those who have not been so fortunate as to have had a course in biology.

Prevention of Epidemics. — The first measure to be adopted, and the one of greatest importance, is educational. Under this heading is included the knowledge: (1) that all germ diseases are due to a specific germ, plant or animal, living in an intimate relation on or in the human body; (2) that all germ diseases are preventable; (3) that keeping our bodies clean, eating clean food, well cooked, and taking plenty of



Robert Koch (1843–1910) attained great renown when in 1883 he discovered the germ which causes tuberculosis. In 1883, he announced that he had found the germ of Asiatic cholera. For several years after he advanced the science of disease by making other discoveries. For some time before his death, he was the director of the Institute for Infectious Diseases in Berlin.

In all of his investigations he applied strictly scientific methods some of which have become a part of the procedure every time a new germ disease is studied. Four steps must be taken before one can be certain that the cause of a germ disease has been discovered. These are: First, a microscopic organism of a particular type must be found in abundance in the blood or tissues of the sick organism; second, a pure culture must be made of the suspected organism; third, this pure culture, when introduced into the body of another similar organism, must produce the same disease; and, fourth, there must then be found in the blood or tissues of the diseased organisms large numbers of these introduced germs.

exercise will do more to prevent germ diseases than anything else.

The second important measure to be adopted to prevent an epidemic *after the communicable disease has appeared* is the prompt quarantine of the first cases and immediately putting into operation the regulations of the Board of Health for communicable diseases.

304. Heredity of Disease. — The term *heredity of disease* is one which has been misunderstood by many people. By the term *heredity* we mean that which is handed on from parents to their offspring. In the case of biological diseases which are caused by some definite plant or animal, it is evident that they cannot be inherited. But when the parents are afflicted with a biological disease, their bodies become weakened and their offspring may have a poor constitution, so that they are more easily affected by disease.

305. Boards of Health. — Communities and physicians have endeavored to prevent the spread of communicable diseases by the formation of boards of health, by quarantine, vaccination against smallpox, immunization against typhoid fever, the use of antitoxin in diphtheria, disinfectants and fumigants.

The term *Board of Health* is applied to a number of individuals, appointed or elected by a nation, by a state, or by a municipality, to enforce the national, state, city, or town health laws and regulations. The local officer of this board is a physician, and in some states, New York for example, is appointed according to the regulations governing the city or town in which he is to serve. The New York state law defines his work as follows:

"Every such local officer should guard against the introduction of such communicable diseases as are designated by the State Department of Health by the exercise of proper and vigilant medical inspection and control of all persons and things infected with or exposed to such diseases, and

provide suitable places for the treatment and care of sick persons who cannot otherwise be provided for."

306. Unsolved Problems in Disease. — In our description of diseases and their prevention a careful distinction was made between those whose cause was known and those whose cause was unknown. In this latter class are placed cancers, tumors, infantile paralysis, scarlet fever, and influenza. In some of these experts believe that they have discovered the cause but are not yet able to control it. The first thing to note about this list is that the number of diseases is very small in comparison with those whose cause is understood. The second fact of great importance is that we cannot take effective steps to prevent these diseases until the causes are known. How is this to be accomplished?

Eventually these diseases will yield their secrets to man just as the others have through his studies on animals. We have become so familiar with the modern ideas of sanitation that the terror and hopelessness of our grandparents as they faced epidemics of smallpox, typhoid fever, yellow fever, malaria, and bubonic plague do not occur to us. These terrible maladies have been conquered, and we today do not know the pests that used to devastate the world at intervals. All of this triumph is due to successful experimentation with animals. Although there are a few people who object to scientific workers using animals for experimental purposes, the great majority agree that, in order to save thousands of human beings from premature death and great suffering, it is necessary to sacrifice a small number of animals.

Ernest Harold Baynes writes on this phase of the subject as follows: "As president of a humane society and as one whose life is spent chiefly in studying animals and in working for their conservation, it is my business to know something about this. I have visited physiological laboratories and medical schools in most of the large cities and many of the smaller ones from Boston to San Francisco, and I can testify

that I have never seen anything in the nature of cruelty in one of them. Since beginning my investigations I have become intimately acquainted with many of our foremost physiologists — vivisectors, if you like — and there are no men or women I should consider more humane, in the broadest and best sense of the word. They treat the animals in their care with kindness and consideration and they reduce to a minimum such discomfort as it is sometimes necessary to inflict in experiments made for the sole purpose of preventing suffering and death. I have witnessed experiments on monkeys, horses, dogs, cats, sheep, goats, rabbits, guinea pigs, rats, mice, poultry, frogs, and fish. Whenever an operation is likely to cause more discomfort than would be experienced in taking an anesthetic, the animal receives an anesthetic and is kept completely under its influence. If the operation is a routine procedure, designed to perfect the skill of medical students, the animal is killed with extra ether at the close of the experiment. The only possible discomfort such an animal can experience is in taking the ether at the beginning."

OUTLINE

- Importance of health
  - Cost of illness
- Kinds of disease
  - Inherited
  - Poisonous
  - Growths
  - Biological
  - Ailments
    - Indigestion
- Communicable diseases
  - Manner of infection
  - Tuberculosis
    - Germs
      - In air
      - In food
    - Getting well
    - Influenza
      - Symptoms
      - Preparation for pneumonia
    - Malaria
      - Source of parasite
        - Anopheles mosquito
    - Yellow fever
      - Source
        - Aëdes mosquito
- Quarantine
  - National
  - State
  - Local
- Worm diseases
  - Tapeworm
  - Trichina
  - Hookworm

- Immunity
  - Vaccination
  - Antitoxin
- Sanitation
  - At home
  - Disinfection
    - Carbolic acid
    - Chloride of lime
  - Antiseptic lotions
- Emergency treatments
  - Cuts
  - Bruises
  - Burns
  - Fractures
  - Poisons
    - Neutralizing agents
- Keeping well
  - Doctors
  - Government inspections
  - Avoiding "carriers"
- Saving children
  - Hygiene
  - Sanitation
  - Parental ignorance
  - Community improvements
- Epidemics
  - Prevention
- Heredity of disease
- Boards of health
- Unsolved problems

SUMMARY

Disease prevents us from working as we do when we are well. Most diseases are unnecessary and preventable, especially those which are caused by plants or animals living as parasites in our bodies. In most of the biological diseases some definite poison produced by the parasite is taken into the body, and this is the chief cause of disease. Tuberculosis, the "great white plague," is caused by a plant named *Bacillus tuberculosis* and often referred to by physicians as "Tb." One can get well if the body is able to overcome the poisons secreted by these minute plants.

Each disease caused by bacteria has its own special history and the symptoms of the disease are definite and distinct. Influenza is probably a germ disease, but the exact kind of bacteria is still unknown. It was epidemic over nearly the whole world in 1918 and 1919. Malaria is a disease due to a protozoan parasite living in the blood corpuscles of man. These parasites are introduced into the blood through the bite of Anopheles mosquitoes.

As a physician knows the nature of a disease and its effect upon the body, he can aid materially in overcoming the illness. Each biological disease is distinct and must have special treatment. Many of these diseases are taken from some one who has the disease. Vaccination, antitoxin, quarantine, and disinfection are measures which help to prevent the spread of germ diseases. It is our duty to keep well, and we can do much toward this by understanding how to avoid the biological diseases.

QUESTIONS

What are the biological diseases? How are these diseases caused? How many kinds of tuberculosis are there? Is diphtheria a germ disease? Are colds germ diseases? Describe malaria. What effect has malaria had upon the settlement of our country? This is a home study question. What is vaccination? What is quarantine? For what diseases are people quarantined? What is the work of the Board of Health? What is the purpose of disinfection? What are the chief disinfectants? What is the danger from epidemics? Name some epidemics. How can they be prevented? What are some of the values of public parks and public baths? What are the powers of health officers? What is your state doing to prevent disease?

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PART IV

APPLICATION OF BIOLOGIC PRINCIPLES TO PLANTS

CHAPTER XXVI

STUDY OF A LIVING GREEN PLANT

Come forth into the light of things. Let Nature be your teacher.
— WORDSWORTH

307. Introduction. — In Part II we have studied some of the most important facts about how animals live and their relations to one another. In Part III we have studied how man lives and how he resembles the other animals in his dependence on conditions around him and in having relationships with other living things. In Part IV we shall study not only how plants live but also how necessary they are to the existence of all forms of animal life.

We have every reason to believe that plants were here ages before man appeared and that animals were using them for food. For a long time man's greatest interest in plants was their use as food. In fact the very word *botany* comes from the Greek *botany*, fodder. Savage peoples used the plants they found growing wild around them. In the course of time certain plants were cultivated and improved for food.

Another interest which primitive man had in plants was their use as medicine. Curiously enough this interest led finally to the first attempts to describe plants accurately. The physicians in one part of the world wanted to be sure that they were talking or reading about the same kind of

plant as some other physician in some other part of the world. So a careful study was made of plants used for medicine by the physicians who were also botanists. One of these men invented the system of naming plants (and other organisms) which is still in use.

Naming and describing plants, collecting and pressing them, became a fascinating study. The more they were studied the more likenesses were found between them and animals — for example, that they need the same conditions to live, that they perform the same vital processes, that they have organs for these processes. The discovery that green plants give out oxygen and use carbonic acid gas was an important one. It emphasized the fact that plants help animals by keeping the air pure. It had long been known that certain animal wastes in the soil helped plants to grow.

The latest great discovery about plants is that they are the only food-makers in the world, — the only means known by which energy from the sun can be gathered, locked up, and stored. Plants make food for themselves and their offspring, and also for animals which eat the plants themselves in some cases and the stored food in others.

This food supplies the energy necessary to plants. They need it for movements, such as climbing, and to overcome obstacles, as when a seedling has to push up through the earth or pierce a layer of leaves to get to the light. It takes energy, too, to make and transport food and to divide cells.

The study of plants at the present time is chiefly biological. We wish to learn how a plant lives as an organism among other organisms and how its organs, roots, stems, leaves, etc., carry on its vital processes. (Review Introduction and Chapter IV.)

Our study will consist largely in observing the adaptations which plants have for living under varied conditions.

308. General Structure of Plants. — Plants, like animals, are made up of organs, — the roots, the stem, the leaves, the

flowers, and usually the fruit. The organs are made up of tissues, and the tissues of cells. Cells vary greatly in size and shape even in the same tissue and even more so in different plants. Separate cells of a unicellular alga, Pleurococcus, are nearly spherical, and so small as to be invisible without the aid of a microscope. Others, like root hairs, are large enough to be seen by the naked eye and very long and slender in shape.

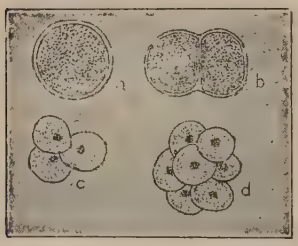


FIGURE 268. — PLEUROCOCCUS. *a*, single plant; *b*, plant dividing; *c*, *d*, groups of plants.

309. Parts of the Cell. — Whatever their size, shape, or function, all cells have certain main parts. These are, first, the *wall*. The wall in a plant cell is usually thicker and firmer than the wall in animal cells, owing to the presence in plants of a substance resembling wood and known as cellulose. The wall in every cell incloses a mass of *cytoplasm*, the second main part of a cell. In the cytoplasm is imbedded the *nucleus*, the third main part of a cell. The nucleus is darker than the surrounding cytoplasm, being composed of a slightly different substance. Besides the wall, the cytoplasm, and the nucleus, a plant cell usually contains spaces filled with *cell sap*, and if the cell is green, it contains small green particles called *chlorophyll bodies* or *chloroplasts*. In the plant, as in the animal, the cell is the unit of both structure and function of all living parts.

310. Protoplasm. — The entire cell is composed of protoplasm. This has one form in the wall, another in the cytoplasm, and still another in the nucleus. Protoplasm is a living substance which has definite characteristics. It is semi-liquid, like the white of an egg. It is transparent or translucent like cooked starch or ground glass. It is mostly water. It absorbs, digests, and assimilates food. It re-

spires and excretes. It repairs its own wastes. It grows. It reproduces. It is irritable to stimuli, — warmth, light, contact, chemicals, electricity.

Cytoplasm is that particular kind of protoplasm which fills the cell wall. The vital processes are carried on by it for the most part. The nucleus is still another particular kind which governs and controls the processes of the cytoplasm.

Protoplasm is made up chiefly of four substances, carbon, oxygen, hydrogen, and nitrogen, with small quantities of

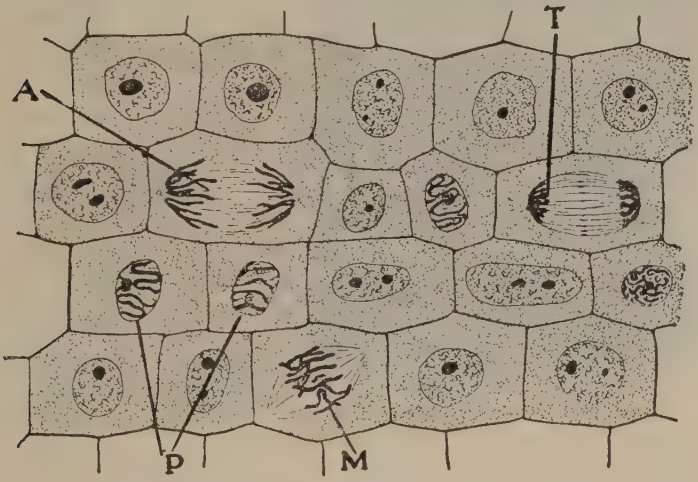
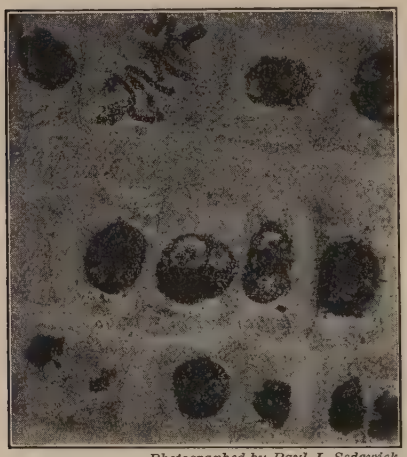


FIGURE 269. — CELLS IN DIFFERENT STAGES OF DIVISION.

M, nuclear matter ready to divide; *A*, nuclear matter dividing; *P*, nucleus divided, and new cells formed. Note other new cells (small).

iron, sodium, phosphorus, potassium, magnesium, calcium, and other chemicals (see page 26). The amounts of these different substances vary from second to second, making it very difficult to describe the chemical composition accurately. However, hydrogen and oxygen in the form of water make up the largest part, as has already been said.

311. Cell Growth and Division. — Cells grow, yet they do not grow on indefinitely, for there is a limit to the size which any kind of cell attains. When this limit has been reached, the cell divides into two smaller ones each of which then grows to full size and divides again. The size of an organism depends largely upon the number of cells it contains. An elephant is larger than a mouse or a horse because it contains more cells than either, just as a business block is larger than a garage or a house because it has more bricks in it. A plant grows, therefore, by adding to cells already there.



Photographed by Paul J. Sedgwick.

FIGURE 270. — PHOTOMICROGRAPH OF THE CELLS SHOWN IN FIGURE 269.

Cells divide by forming a new wall through the middle or by a process of pinching in two, called *fission*, or by a more complicated process, which is shown in Figure 269. The method of division depends on the kind of cell and the function it performs.

LABORATORY STUDY OF CELLS

Structure. — Examine a bit of the thin skin between the layers of an onion, using a prepared slide if possible. Study first under low, then under high, power of a compound microscope. Note that it is composed of cells. Are they all the same size? The same shape? Draw a small group as they appear under high power. Label (1) the *wall*, the inclosing portion, (2) *cytoplasm*, the substance within the wall, (3) *nucleus*, a dark portion imbedded in the cytoplasm. Is there a *vacuole* (this appears as an empty space)? What is the greatest number of cells that touch any one cell?

Compare the drawing you have made with other parts of plants (Figures 268–269), and with organs of animals. (See Figure 281.) Try to find out how many times the microscope has magnified the cells you drew. Try to compute the number of cells there must be in a square millimeter of onion skin; in a square inch.

The cytoplasm of a cell of Spirogyra can be condensed and drawn from the walls by soaking it for a few seconds in salt water or in sugar and water. This also shows the wall clearly as separate from the cytoplasm. A hair from a squash seedling shows vacuoles well. Use the high power of a compound microscope.

Protoplasmic Activity. — Place the tip of a leaf of elodea, nitella, or chara, or a hair from a squash seedling on a slide, in water. Support a cover glass with bits of pith or glass so that the cells will be free from pressure. Place under high power of a microscope. Gently warm the slide by laying on it one that is slightly warmer. Examine cells for circulatory movement of protoplasm, especially near the walls of the cells. Note the direction of the motion.

312. Comparison of the Life Needs and Life Functions of Plants and Animals. — It is a matter of common knowledge that an animal deprived of food and water will die in a short time, and that it will smother if it has no air, and freeze to death if exposed to too great a degree of cold. In other words, an animal cannot live without food, water, air, and a moderate degree of warmth. This being so, we speak of them as the life needs of animals. Plants have exactly the same life needs, for they, too, are organisms, composed of cells made of protoplasm.

An animal, to live and thrive, needs to secure food, then to digest it, to circulate the digested food, assimilate parts of it, cast off wastes formed, and respire. These processes of animals are their life functions, all of them necessary for the carrying on of their individual lives. In addition they must reproduce in order that the race may not die out.

Plants have exactly the same life functions and in addition, green plants have a life function which no other organisms have; namely, *photosynthesis* (see page 37). This is the process of making carbohydrates, one of the classes of foods (see

page 27), from raw materials, taken from the soil and from the air, under the influence of sunlight. Green plants are, then, the only means in the world of keeping up the supply of food, a fact which makes them, fundamentally, the most important organisms in the world, since all life, even their own, depends on their being able to furnish the food needed for existence. The more we think about this fact, the more wonderful it seems; and the more we study about the relations of green plants to other organisms, the more deeply we appreciate what a delicately adjusted and marvelous place the earth is.

In many ways, flowering plants are more intricate organisms than animals. Without the ability to change their environment, they must depend upon the soil as they find it, rich or poor, wet or dry, soft or hard, to furnish them water and such food materials as come to them in liquid form. Without being able to seek shelter, they must take sun or shade, heat or cold, rainy weather or dry, pure or impure air just as each comes. Lacking organs of offense or defense against other plants they must contend with them for moisture, air, and light, besides being subject to the attacks of organisms which injure them. In addition to making of themselves the best plants possible under the conditions, they must produce numerous offspring, furnish each new plant with a supply of food, and send them all out into the world to meet and to make use of such conditions as they may find.

An examination of the plants in any garden or yard will show that varying degrees of success have been attained. In every case, however, it represents the best that could be done under the circumstances. When we consider that plants have not intelligence such as animals possess, it appears all the more remarkable that they can accomplish so much, often under very adverse conditions. The biologist's great interest in plants is in the ways they adapt themselves

to carry on their life processes under all sorts of conditions, as well as in the processes themselves. Those who raise plants can expect success only as they are able to supply the conditions under which each plant thrives best, and to control conditions and organisms which may be unfavorable.

SUMMARY

The green plant is an organism which consists of root, stem, leaves, flowers, and later, fruits. Plants are composed of cells, the main parts of which are wall, cytoplasm, and nucleus. Plant cells have firmer walls than animal cells, due to the presence of cellulose. Protoplasm is the living substance of which the cells are composed and by which the life processes are carried on. A cell is a bit of organized protoplasm, the unit of structure and function of all living parts of the plant.

Plants, like animals, require food, air, water, and warmth. Like animals, they digest, circulate, and assimilate food, cast off waste, respire, and reproduce. In addition, green plants have a life function, photosynthesis, which is peculiar to them. Photosynthesis is the process of combining into foods, under the influence of sunlight, raw materials from the air and the water obtained from the soil. Since this is the only way that food is made in nature, it follows that everything that requires food is dependent upon plants to make it.

QUESTIONS

How are plants and animals alike in their needs? In their structure? What is photosynthesis? What organisms perform it? Why is it so important a function?

CHAPTER XXVII

LEAVES — THE PLANT'S WORK-SHOP

I sing the first green leaf upon the bough,
The tiny kindling flame of emerald fire.
The stir amid the roots of reeds, and how
The sap will flush the briar.

— Clinton Scollard

313. General Structure and Parts of a Leaf. — The leaf is the most important organ of the plant, for in it are carried on most of those processes which pertain to the life of the plant itself. Because it is so

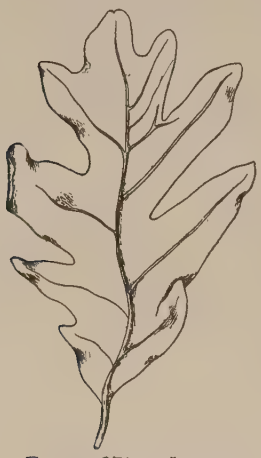


Figure 271. — Leaf of Oak.

The blade, though deeply lobed, is simple, *i.e.*, undivided.

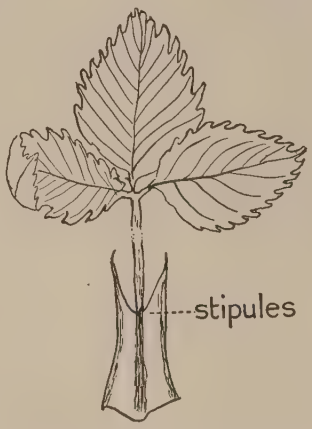


Figure 272. — Leaf of a Strawberry, Showing Stipules.

important an organ and because it has so many kinds of work to do, it has many adaptations in form, position, and

structure which fit it to do its various kinds of work, besides giving individuality to plants. We shall study the work of the leaves first in order that we may more easily understand how the structure, form, and position of the various kinds of leaves adapt each to its work.

The main part of a leaf is the *blade*. The *petiole* (Latin, *petiolus*, fruit stalk) is the part by which it is attached to the twig. This sometimes has small projections called *stipules* at the base.

314. Venation. — The leaf of most plants contains ribs or veins which determine its main form and serve to keep it firm. There are two main types of arrangement of veins. The first, that in which there are a few veins of about the same size which run side by side without branching from the base of the leaf to the tip. These are the parallel-veined leaves found in grasses, lilies, and most other monocotyledonous plants. In the second type, the netted-veined leaves, a few main veins branch and divide, filling the spaces between them with a fine network of small veins. The main veins may have a palmate arrangement, as in the palmately-netted-veined maple leaf, or they may branch from a central vein, as in the pinnately-netted-veined leaf of the elm. In such a leaf, each branch of the mid-vein usually ends in a point of the margin, or in a notch.

FIGURE 273. — LEAF OF ELM.

Simple leaf with a serrate margin and pinnately-netted venation. Note that the leaf is asymmetrical at the base. The general shape is ovate oblong, with a sharp apex.

315. The Arrangement of Leaves. — In general, leaf arrangement falls into two groups: (1) small leaves arranged all along the length of a branch — the spiral arrangement, the simplest form of which is found in the elm, where the leaves are in two rows alternating with each other; (2) a few

large leaves at the end of a branch, as in the maple, where the leaves are in pairs, each pair alternating with its neighbors. In the first case the shape of the leaves is such that all the space is occupied without much overlapping; in the second, every leaf is fully exposed to the light by the lowest

FIGURE 274.

Showing the arrangement by which leaves receive as much light as possible.

leaves having the longest petioles. The leaves of a maple illustrate this.

A rosette is formed by leaves, arranged spirally on a very short stem, with long petioles nearest to the ground, shorter ones alternating with them and filling the spaces. The

dandelion, evening primrose, and thistle show rosettes. Light that has passed through one leaf is of little value to a leaf below it. Some plants have finely divided leaves, an adaptation which prevents any leaf shutting off all the light from those below. Angular leaves, round leaves, and leaflets are all adaptations to use up all the space without overlapping. The leaves of ivy growing on a wall are so arranged

FIGURE 275. — LEAVES OF YOUNG PLANTS OF POKEWEED.
Note their large size, and their arrangement to prevent shutting off the light from those below.

as to fill all the spaces and not to overlap. They form what is called a leaf mosaic.

Whatever the arrangement of leaves on any particular plant, the object is to expose the leaves most advantageously to light and air, incidentally preventing their shading one another, which sometimes causes a vertical branch and a horizontal branch of the same plant to show a different arrangement of leaves.

316. Simple and Compound Leaves. — A leaf is said to be *simple* when the blade is all in one part, and *compound* when it is divided into three or more leaflets. The apple and the maple have simple leaves, the clover and the horse-chestnut have compound leaves. A compound leaf is one in which the leaflets branch from the midrib, as in the rose or the locust; there are three leaflets, as in the clover and oxalis, or one in which there are five or more leaflets, as in the horse-chestnut and woodbine.

FIGURE 276. — PALMATELY COMPOUND LEAF OF WOODBINE.

There is a reason for these compound leaves. A leaf with a blade as large as the combined surfaces of a compound leaf would be much more easily torn by the wind, and would cut off more light from the leaves below. Some leaves are very finely divided, being many times compound, like the carrot and the yarrow.

317. Dropping of Leaves in Autumn. — Before a tree sheds its leaves, it withdraws all the food they contain and stores it in some other portion of the tree. What remains is largely

the mineral matter that was not needed in the manufacture of food. This is waste, and so of no further use to the tree. The shedding of leaves thus serves two purposes — to reduce transpiration [1] and to get rid of waste.

Autumn colors appear to be due to a combination of causes, among them the removal of chlorophyll which has covered up other colors, and chemical changes which take place in the leaf after its work is done.

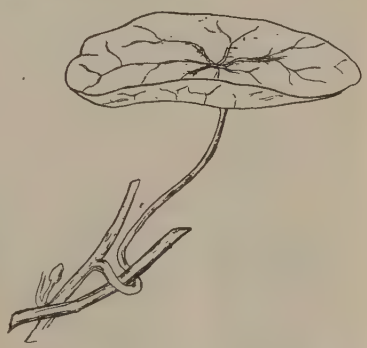


FIGURE 278. — LEAF OF NASTURTIUM.

The petiole is attached at the middle of the back of the blade. The blade is orbicular, with entire margin. Note the twining petiole, a device for holding up a weak stem.

318. Modified Forms of Leaves. — Some leaves, like the sundew, pitcher plant, and Venus's flytrap, are adapted for catching insects for the use of the plant as nitrogenous food. In others, as clematis, the petioles are used to help the plant in climbing. In the case of the pea, leaves have become modified into tendrils which are used in helping the plant to climb. (See Figure 277.) The tendrils of grape-vines and various kinds of ivy are also modified leaves. Still others have their leaves modified to thorns for protection, as in the thorny locust and barberry.

FIGURE 277. — TWINING PETIOLE OF CLEMATIS.

[1] The act of sending off watery vapor.

319. Leafless Plants. — In plants like the cactus, already mentioned, the work usually done by leaves is performed by the stem. Asparagus is a plant in which a much-branched stem serves as leaves, the true leaves being almost invisible scales. Another example is the plant commonly called smilax, in which the branches very closely resemble leaves.

Other plants which have scales instead of leaves are dodder and Indian pipe, both of which use food already prepared.

FIGURE 279. — LEAVES OF BARBERRY.

These leaves, all taken from the same bush, show the transition from normal leaves to thorns for protection.

320. The Movement of Leaves. — Most movements of leaves are due to unequal growth caused by the light being brighter on one side than on the other. Some leaves on this account "follow the sun." Others, like the compass plant, turn their edges to direct sunlight which is too strong for them. The clover and oxalis, which fold their leaflets at night, illustrate the so-called "sleep movements" of plants.

The movements of sensitive plants are due to the effect of the shock caused by touching them. This causes the cells of an organ at the base of the petiole to become soft and flaccid through loss of water which passes into the inter-cellular spaces, allowing the whole leaf to droop and the leaflet to fold.

FIGURE 280. — INDIAN PIPE.

This is white. It uses food already prepared, as it lacks chlorophyll.

HOME WORK, MOVEMENTS OF PLANTS

Place young seedlings in a window for a day. Which way do they turn? Turn the plants around and note how long it takes them to become erect; to become bent towards the window again. Keep careful records, using camera or drawings.

On a sunny day set a stick parallel with the tip of a ragweed or other tall, slender weed. Set another stick about noon and another about three o'clock. Draw a diagram, or use your camera to show the changes in the position of the tip of the plant. Observe leaves of clover, and young daisy blossoms. Do they change their positions with the sun? What other plants do this? Does the age of the plant make any difference with its ability to change position?

Bend a grass stem and fasten it flat. After a day or two observe its position. What changes have taken place?

Write notes telling what you have been able to observe in the cases above, and in any others which you may have noticed without being directed to do so.

321. Structure of a Leaf (Cross Section). — While leaves vary greatly in number, size, position, and shape, the work that they do is very similar for each plant. A typical leaf is covered with a layer of thin cells called the *epidermis*. In

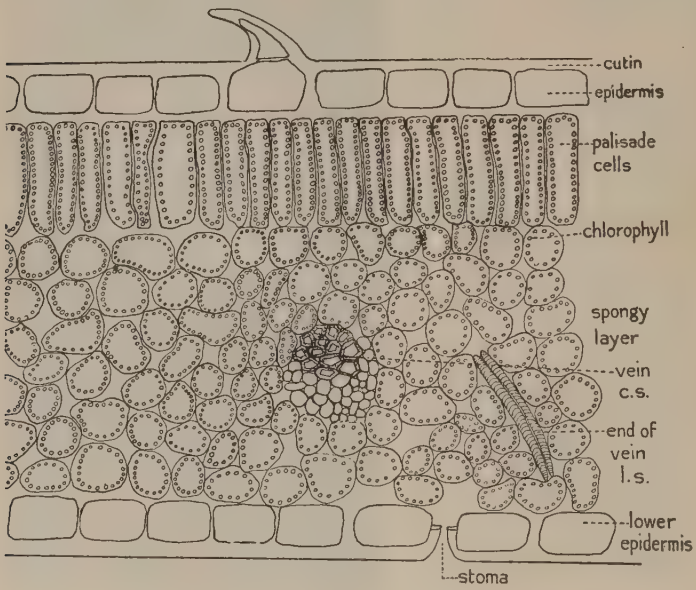


FIGURE 281. — DIAGRAM OF STRUCTURE OF A LEAF.

hot, dry regions the epidermis has a heavy coating of cutin, a substance which prevents evaporation. The epidermis on the under side of the leaf is thinner and has less cutin than that on the upper side of the leaf. It is pierced by many openings called *stomata* or air pores (Greek, *stoma*, a mouth) which allows the entrance of air and the exit of water and gas. Between these two layers of epidermis is the *mesophyll* (mĕz′ō-fĭl: Greek, *mesos*, middle; *phyllos*, leaf) of the leaf,

divided into two regions, (1) the *upper* or *palisade* composed of slender, elongated cells placed side by side in upright position, (2) *spongy layer* consisting of rounded cells, loosely arranged with many air spaces between them. It is in this spongy layer that the most chlorophyll is found.

LABORATORY STUDY OF LEAVES

Draw a leaf of geranium (or other plant). Label (1) blade, (2) petiole, (3) stipules, if any. Notice the arrangement of the veins as you look through it.

Remove the leaves from an onion. Note the thickened bases and how they are attached to the short stem.

Stand a stalk of celery in water tinted with red ink. Cut across it after two hours and observe the position of the vascular bundles.[1] Trace them into the leaf.

Pull off leaves of dock and plantain and observe the tough vascular bundles.

Study a bit of epidermis with a microscope. Draw. Label stomata, epidermal cells, guard cells (2 around each stoma). Study a cross section. Label *cuticle*, outermost layer, *epidermis* (upper and under surfaces), *palisade layer* under top epidermis; *spongy layer*, body of leaf; *vein* Which cells contain chlorophyll? Where are the air spaces?

HOME WORK ON LEAVES

Pull up or cut off a large burdock plant. Measure the area covered by the lower leaves. What else grew in this area? What is its condition? Why? Do the same with plantain, dock, dandelion, knotweed, and other weeds in dooryard or garden. What plants form rosettes of leaves in the fall?

Break off leaves of burdock, plantain, dock, and pieplant. Note the strings (fibrovascular bundles).[1]

Make a collection of leaves to illustrate the various kinds of shape, apex, margin, and base.

Study the arrangement of leaves on the plants you see to determine how it is adapted to secure light for all the leaves.

What effect does the wind have in helping or hindering leaves to get light?

What happens when you make a "bag" from a leaf of live-for-ever?

[1] Elongated cells or vessels for the circulation of sap.

322. Adaptations of a Leaf. — The cutin of the epidermis prevents evaporation of water. The stomata allow air to enter and water and gases to pass out. Stomata themselves show many adaptations: (1) *Position.* In a leaf that extends horizontally from a plant, most of the stomata are on the under side, an adaptation which prevents their being closed by water. In leaves which float upon the water, the stomata are on the upper surface for the same reason. In plants with erect leaves, the stomata are distributed on both sides. In the cases of desert plants, the stomata are sunk below the level of the epidermis, or they are covered by hairs or wax, both of which tend to keep them from being filled with water and to prevent undue transpiration (evaporation). (2) The *structure.* This shows other adaptations. The opening is surrounded by two cells, called *guard cells*, which have the property of absorbing water from the atmosphere. When these cells are full of moisture, they are plump or *turgid;* when they have only a little water they are flabby or *flaccid.* The turgid guard cells leave the stomata wide open and allow free passage of air into the cell, and of water and gas out of it. Flaccid guard cells, on the other hand, make the opening small, decrease the amount of air that enters, and prevent undue evaporation from the inside of the leaf. Although each stoma is very small, they

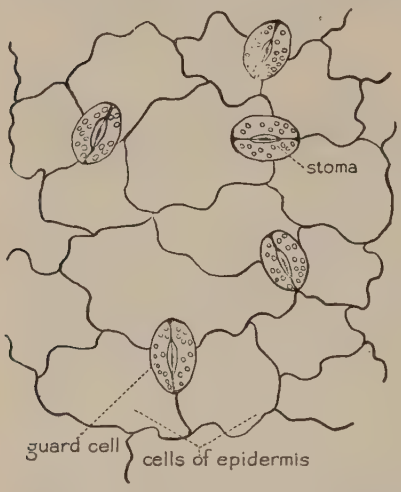


FIGURE 282. — BIT OF EPIDERMIS OF LEAF.
The epidermal cells lack chlorophyll. The guard cells of the stomata have it.

are so numerous that their combined action accomplishes a great deal. A square millimeter of the under surface of a lilac leaf contains 330 stomata, that of white birch, 237.

Most of the grasses show adaptations (1) in having very narrow leaves, fitted to grow close together; (2) in wavy edges if they are long, an adaptation which prevents their being torn by the wind; (3) in a clasping base, helping to strengthen the stem, and (4) in a collar which prevents water from running down between the clasping base and the stem.

323. Functions of Leaves. — The life processes carried on by the leaf are (1) *photosynthesis*, peculiar to plants having chlorophyll, green coloring matter; (2) *respiration*, common to all living protoplasm; (3) *digestion*, (4) *circulation*, (5) *assimilation*, and (6) *excretion*. All but the first are much the same as the processes of the same names in animals. *Transpiration* which, like photosynthesis, is peculiar to green plants, while not one of the life processes, is made necessary by them.

The work that a leaf does is of greater importance than anything else about it. We study its structure in order to understand how it is able to carry on this work. For the same reason we study the arrangement of the leaves on the stem, and their form, which has a close relation to arrangement.

324. Photosynthesis. Carbohydrate Manufacture. — The word photosynthesis (Greek, *phos*, light; *synthesis*, composition) means putting together by means of light. It is the process of manufacturing carbohydrates from raw materials, a vital process performed only by green plants.

The Process. — Many facts about this process are not well understood, but we can state a few with certainty: (1) that in the manufacture of carbohydrates by photosynthesis, carbon dioxide is used as one of the raw materials, the source of this gas being the air, in which it exists 3 or 4 parts in 10,000, and the waste of the plant's own respiration; (2) that another raw material used is water, which is taken up by

roots; (3) that some oxygen is left over as a by-product and given off as a waste of the process of photosynthesis; (4) that chlorophyll, the green coloring matter of plants, is essential; (5) that light is necessary not only to develop the chlorophyll but also to enable it to manufacture carbohydrates; (6) that another necessary factor is a moderate degree of warmth.

The Products. — Carbohydrates are the first visible product of photosynthesis, but proteins and oils result from later processes, probably very similar to photosynthesis, which take place in the green leaf.

The Use Made of the Products. — The carbohydrates, proteins, and oils thus made are used in three ways: (1) some of it is digested in leaves and built up into new protoplasm; (2) some of it is stored in the leaves to be used later; (3) another portion is stored in other parts of the plant, as in the potato, in seeds, buds, and roots.

Comparison. — The process of photosynthesis may be compared to any other manufacturing process which requires:

1. A factory — in this case, green leaves.
2. Machinery — the plant cells containing chlorophyll.
3. Power — light from the sun, a form of energy.
4. Raw materials — carbon dioxide and water, and small portions of nitrogen and other chemical substances which are dissolved in the water taken in by the roots.
5. Working hours — daylight.

In this comparison the *products* are the carbohydrates and other forms of food which are made from them, and the *by-product*, oxygen. This manufacturing process disposes of its products (1) by storing them on the premises, the leaf; (2) by using them on the premises, digesting them to make more protoplasm; (3) by sending them away to other parts for storage, or immediate use; (4) by using them to make other food substances, namely, proteins, and fats or oils.

The Importance of Photosynthesis. — The importance of photosynthesis cannot be overestimated. It is the only

natural process in the world by which raw material can be changed into food and by which energy can be stored up for future use. The plant makes use of this stored-up energy to produce new leaves, flowers, etc. Animals, which have not the ability to manufacture food from raw materials, depend directly or indirectly upon green plants for their supply of food. Besides making all the vegetable food in the world, plants, in using the carbon dioxide produced by animals, keep the air free from excess of it and so make it safe for animals to breathe. They also, by the same process, keep it well supplied with oxygen. Photosynthesis is the most important work of the leaf, as well as the vital process on which all other vital processes, both in plants and animals, depend.

325. Transpiration. — This is the process of evaporation which takes place in plants, water in the form of vapor escaping through very small openings in the leaves called *stomata*. It is not one of the vital processes, but closely connected with them. Its only similarity to perspiration in animals, to which it has sometimes been likened, is that water is given off through openings in the outer covering of the plant. Transpiration is unavoidable because the roots of a plant usually take up more water than is needed for the vital processes, and because this excess accumulates in spaces which communicate with the outside through the stomata. The use of the stomata is to allow air containing carbon dioxide to pass into the leaf, and excess oxygen to pass out. Incidentally, however, water passes out too. When transpiration is too rapid, the plant is deprived of needed water. Since transpiration is a menace to the well-being of a plant, numerous devices have been developed for regulating it.

1. The surface of a leaf is covered above and below by a layer of *cutin*, a transparent substance impervious to water, perforated only where stomata occur.

2. The stomata are on the under side of the leaves in

most plants, this position being less favorable to transpiration than the upper side.

3. The stomata contain guard cells which regulate the size of the opening by absorbing moisture or losing it. When the guard cells are full of water, they are plump or *turgid*, leaving the stoma wide open. When they are soft or *flaccid* from lack of water, they collapse, partially closing the stoma.

4. In addition to this regulating device the stomata may be under coverings of hair or wax to make evaporation less rapid, or they may be at the bottom of a very thick layer of cutin.

5. A leaf may still further check transpiration by changing its position or by rolling its edges together. Corn leaves during a very dry period illustrate this.

6. Another device is seen in cactus plants, which have a greatly reduced surface. The stem in these plants is green and it contains stomata, thus enabling it to do the work of leaves.

When the moisture in the air exceeds a certain quantity, evaporation does not take place readily, causing too much water to accumulate in the plant. To prevent damage from this condition, plants have modified stomata, called *water pores*, at the ends of the veins. These contain cells which burst under pressure, allowing the water to exude. This process is known as *guttation*, and the drops so formed, as guttation drops. These are often seen in the morning on the ends of grass blades, and on the points of leaves that have serrate margins, like the strawberry. Guttation drops are sometimes absorbed by the plant and sometimes they evaporate, depending on the needs of the plant and the amount of moisture in the air, or, as we say, the *degree of humidity*.

The amount of water that leaves a plant in a day by transpiration alone is very great. For example, a moderate-sized sunflower plant will give off a quart a day under ordinary conditions.

PROJECT

1. By observation, try to find out the conditions of weather which produce guttation in plants.

2. Find out all you can about dew and the conditions under which it is produced.

326. Excretion. — Excretion in plants is the same as in animals in this respect, that it is getting rid of material or substances which are no longer of use to the plant. It very often happens, however, that these are not removed from the plant as in the case of animals, but are simply stored where they can do no harm. An example of this is the crystals of calcium oxalate which give to sorrel, or sour grass, its sour taste. The line between excretion and the secretion of certain substances, such as the oils in peppermint plants, is not easily drawn. In the case of the secretions, however, they often serve the purpose of preventing animals from eating the plants.

327. Digestion of Food. — Although the plant manufactures food from raw materials, it cannot make use of it until it has been digested. The process of digestion takes place chiefly in the leaf, and the digested food is carried to all parts of the plant which need it through the vascular bundles. There are many facts about digestion in plants which are not so well understood as this same process in animals. It is known, however, that the enzyme, *diastase*, which digests starch, is secreted by the protoplasm of the cells and that it is very similar to ptyalin, the ferment in the saliva of animals which digests starch.

328. Circulation. — Circulation in plants differs from circulation in animals in not having any central organ for keeping the fluids in motion and in the substances which the vessels contain. The xylem of a fibro-vascular bundle carries water taken up by the roots from the soil to the leaves, where it is combined with carbon from the air and built up

into foods. The digested foods are carried from the leaf to the parts of the plant which need them in the phloem part of the vascular bundle, so that, generally speaking, we have an ascending stream of water in one part of the bundle and a descending stream of digested food in the other part. The term *sap* is used to include both. Sap is moved by the combined influence of osmosis (root pressure), transpiration, and possibly other factors.

FIGURE 283. — SKELETON OF POPLAR LEAF.

Note the epidermis still remaining on part of the leaf. Poplar leaves skeletonize very easily. This was picked up on the street.

329. Respiration. — An important life function of the leaf is respiration. Respiration in plants is exactly the same as respiration in animals. That is, every living cell requires oxygen, combining it with some of its protoplasm, releasing energy for the work of the plant and forming carbon dioxide and other wastes in the process. Respiration is most easily studied in plants like toadstools, which cannot perform photosynthesis, and in sprouting seedlings, which have not developed chlorophyll.

330. Assimilation. — This is the actual taking up by the plant cells of such parts of the digested food as they need. By assimilation the old cells are repaired and new ones formed. It is a building-up process which results in the growth of the plant till it reaches the stage of maturity and in maintaining it at that size.

HOME WORK ON PHOTOSYNTHESIS

Make a list of the plants that are used for food. Look up in an encyclopedia the amounts of each produced in a given year. Make a list of the industries which are dependent on agriculture. Obtain information concerning the number of men employed in each.

What uses are made of starch and sugar aside from food?

What are the sources of the protein used for food? Which of these depend directly upon photosynthesis? Which indirectly upon it?

LABORATORY STUDY

Necessity for Light. — To show that light is necessary for photosynthesis, fasten thin discs of cork to the upper and under sides of a leaf with clips, completely shutting off the light. Stand the plant in the bright light for half a day, then remove the corks from the leaf and the leaf from the plant. Heat enough 60 per cent alcohol to cover the leaf in a shallow glass dish. This may be done by setting the dish into hot water. Keep hot for half an hour, or till the chlorophyll is removed from the leaf. Turn off the alcohol and put drops of weak iodine on the leaf. Note that the circle covered by the cork discs shows little starch or none, as indicated by the faint blue color or by lack of color.

Make a similar test by comparing a leaf from a plant that has been in the dark twelve hours with one that has stood in the bright light for the same time, using alcohol to remove the chlorophyll and iodine for a test for the presence of starch, as before.

Necessity of Chlorophyll for Photosynthesis. — The plant known as Vinca or the ornamental maple has variegated leaves. If a leaf from either of these plants is placed in alcohol, it becomes uniform in color. If it is then washed and placed in iodine, the iodine brings out the areas where the starch was formed but does not bring the areas that were of a light color. Such a leaf shows the necessity of chlorophyll in the manufacture of starch.

The blanching of celery is a practical application of the fact that chlorophyll cannot develop in darkness. The stalks are either covered with earth, or the rows of celery are shut in from the light by long strips of black paper which allow only the top leaves to project into the light. The white leaves in the heart of a head of cabbage, lettuce, or in opening buds in the spring are also accounted for by the fact that they are shut off from light by the leaves which surround them.

331. Protein and Fat Formation. — Proteins are made from starches and sugars, carbohydrates, by the addition of

nitrogen. The process takes place in the leaf, as does photosynthesis, but it does not require light or chlorophyll as photosynthesis does. Fats, which contain the same substances — elements — as carbohydrates, are made by tearing them down and building them up again in a different relation. In any case, a supply of carbohydrates is necessary for the formation of other kinds of food. One plant family makes most of the vegetable protein in the world; that is, the Pulse family, to which bean, pea, and clover belong.

LABORATORY STUDY

Liberation of Gas. — To test the nature of the gas given off by growing algæ when making food collect a quantity of algæ, elodea, or sagittaria and place it in a deep glass jar in the sunlight. When bubbles begin to show, place an inverted funnel over the algæ. Fill a test tube with water and invert it over the upright stem of the funnel. When an inch or more of the gas has collected in the test tube, remove it carefully, and thrust a glowing splinter into it. Increased brightness of the glow or bursting into flame shows that oxygen is present.

Land Plants. — Gather leaves of land plants which have large smooth petioles, such as calla, dock, and rhubarb (pieplant). Put them into dishes of water and stand the dishes in the light. When bubbles appear on the petioles or on the under sides of the leaves, collect the gas. Invert a test tube full of water and pass it gently over the surface of the leaf or petiole, inclining both the leaf and the tube to catch the gas as the bubbles are dislodged. Test the gas with a glowing splinter.

Another method, less accurate, but less trouble, is to dislodge as many of the bubbles as possible by a sharp blow on the container, causing the gas to pass into an inverted funnel, or to be more or less confined under a cover. A smoldering splinter will glow more brightly or burst into flame according to the success of the experiment.

LABORATORY WORK ON TRANSPIRATION

Liberation of Water Vapor. — Turn the under side of a geranium leaf or other large leaf so it lies against a cool window pane, holding it there in some way if necessary. After half an hour remove it and note the drops of moisture which resulted from transpiration. Try other leaves in the same way. Fasten a watch crystal to the *under side* of a

leaf, using clips to hold it and vaseline to make the edges air tight. Do the same with the *upper* side of another leaf. Which side gives off moisture as shown by drops on the watch crystal? Plunge a large leaf into water and set in the sun. On which side do bubbles appear? Wait half an hour. What kind of gas do they contain? What process in the leaf produced them? If you cannot answer this now, try again after reviewing photosynthesis.

Take three leaves from the same plant. Coat one on both sides with paraffine or vaseline, one on the upper side only and one on the lower side only. Lay them aside till your next laboratory period. Describe all three. Which is least wilted? Why? Lay them all aside till all are wilted, observing them now and then and making a record of what happens. Use an uncoated leaf as a check.

Hold a leaf up to the light and notice the arrangement of the veins and the soft parts.

Thoroughly water a fern or other plant growing in a jar. Cover the earth with tinfoil, oilcloth, or paraffine to prevent evaporation from the surface. Weigh it carefully, then let it stand on the scales, adding weights from time to time to take the place of the water lost by evaporation. If the plant has large leaves, remove them; after the experiment is completed, draw their outline on cross section paper and find their combined surface. Compare it with the amount of water lost. At the same rate, estimate how much would be given off by a plant with a leaf surface ten times as great, or as many times as great as you please. Describe the whole experiment in writing, illustrating with sketches or photographs, as you please.

Cover a small fuchsia or balsam overnight with a bell jar. Where are the guttation drops found? Why do they form there? Cover young plants of oats, wheat, corn, or grass in the same way. Where are the drops formed on them? Make drawings of one or more kinds of leaves used in this experiment. Write notes telling what you discovered.

332. Economic Uses of Leaves. — The leaves of all the grasses as well as their stalks are used as food for cattle. Man uses for food the leaves of cabbage, lettuce, spinach, celery, parsley, kale, kohlrabi, and Swiss chard; and as a beverage, the leaves of the tea plant. The leaves of wintergreen, spearmint, peppermint, and sage are used for flavoring, and the leaves of some plants, mullein, boneset, catnip, peppermint, wintergreen, wormwood, and many others for

medicine. In the tropical countries some broad leaves are used for thatching — thus affording shelter.

HOME STUDY

Using an encyclopedia, find out all you can about the making of extracts. Make a list of plants which are used as flavoring. Make another list of plants the leaves of which are used as medicine. What plants produce essential oils? For what are they used? What is meant by a "synthetic oil"?

What plants are used as perfumes? How are perfumes made?

Look up in the dictionary the meanings of such terms as decoction, infusion, vermifuge, expectorant, soporific, and others you find in connection with the uses of leaves of medicinal plants.

OUTLINE

- Structure of leaf
  - Blade
  - Petiole
  - Stipules
- Venation
  - Parallel
  - Netted
  - Palmate
  - Pinnate
- Arrangement
  - Spiral
  - Alternating
  - Rosette
- Simple leaves
  - Apple
  - Maple
- Compound leaves
  - Clover
  - Horse Chestnut
- Falling leaves
  - Reduce transpiration
  - Get rid of waste
- Modified forms
  - Tendrils
  - Thorns
- Leafless plants
  - Asparagus
  - Smilax
- Movement of leaves
  - Follow sun
  - Fold at night
- Cross section
  - Epidermis
    - Cutin
    - Stomata
  - Mesophyll
    - Palisade
    - Spongy layer
- Adaptations
  - Prevent evaporation
  - Allow entrance of air
    - Exit of water
- Functions
  - Photosynthesis
  - Respiration
  - Digestion
  - Circulation
  - Assimilation
  - Excretion

Photosynthesis
- Process
- Products
- Use
- Comparison
- Importance

Transpiration
- Stomata
- Regulation
- Cutin
- Guard cells
- Wax
- Curling edges

Protein and fat formation

Economic uses

SUMMARY

The leaf is the organ of greatest use to the plant in performing the processes which maintain its own life. In the leaf food is manufactured, digested, and assimilated. Its cells carry on excretion and respiration to a greater degree than any other cells of the plant.

The purpose of the shape, size, and arrangement of leaves is to enable them to get the greatest amount of light and air possible.

On the process of photosynthesis depends the whole world's supply of food.

QUESTIONS

Name the processes carried on by the leaves. Which is of the greatest use to man? Why? What is the object of leaf arrangement? Describe the structure of a leaf. What two purposes are served by veins? Mention at least four plants that have peculiar leaves. Describe each and tell how it helps the plant.

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CHAPTER XXVIII

STEMS, THE PLANT'S TRANSPORTATION SYSTEM

Two lovely berries molded on one stem. — SHAKSPERE

333. Kinds of Stems. — The stem is that part of the plant which connects the roots and the leaves. There are only two kinds of stems so far as structure is concerned. In one kind, the fibro-vascular [1] bundles are scattered throughout the pith. In the other, they are arranged around the outside of the stem with pith in the center and, in the early stages, with pith between them also. Stems with scattered bundles are always found in plants that have one cotyledon,[2] as corn, grass, palm. Stems with fibro-vascular bundles arranged around the outside are always found in plants that have two cotyledons, as the bean, and all woody trees.

A monocotyledonous stem is covered with a hard rind which contains silica, a substance like glass which makes it hard and strong. In grasses the stem is hollow, and the bundles are around the edges, some of them passing off at each node into the leaf which arises from it.

In a woody stem there are only a few fibro-vascular bundles when the stem is young. As the stem grows in thickness to support more leaves, new bundles grow between those

[1] Vascular bundles are a part of the conductive system of the plant. They are in stem, root, and leaves. In the leaves we call them veins. In celery they are the "strings" (see Figure 288).

[2] The rudimentary leaf in the embryo of plants, the lobe of the seed.

already there to carry water to the new leaves. A complete ring is thus formed, with a few pith cells crowded between the bundles. As the stem grows, the bundles take up most of the space, so that a mature stem has a much smaller pith than a young one.

334. Functions and Adaptations of Stems. — The stem is of use to the plant for support, in being the place for the attachment of leaves, and in providing a path for the vessels which carry water from the roots where it is gathered to the leaves where most of it is used. A fourth use of stems is for the storage of food, as in the potato. A few plants make use of stems for propagation, as in the case of the strawberry and the black raspberry. (See page 480.)

It is adapted to its work (1) in being compact and sturdy, enabling it to bear weight; (2) in branching, to afford a larger number of points for the attachment of leaves; (3) (in some cases) in being provided with thorns or briars, as in the blackberry and rose, to protect it from being injured by animals; (4) in being covered with a strong epidermis or, in woody stems, with bark which protects it from outside injury and keeps it from drying up; (5) in plants which grow in the water, in having large air spaces to carry air to the roots which lie in the mud at the bottom of the water.

The hard outer rind makes a monocotyledonous stem rigid, and the pith makes it light. Monocotyledonous stems are usually tall and slender and do not sustain great weight. A dicotyledonous stem is usually stouter, and its woody structure enables it to bear a heavy load of leaves and fruit.

335. Position of Stems. — Stems assume a variety of positions, but that which serves the purpose of most plants best is the upright, independent position. Any tree illustrates this kind of stem. A few which are upright keep that position by twining or by clinging to an upright support, which may be some other plant. These plants have comparatively weak stems. Creeping or trailing stems lie on

the ground with only the tip erect. This position is illustrated by the habit of the ground pine and by the running blackberry.

336. The Duration of Stems. — The length of life of a stem depends upon its habit in producing seeds. An annual or herbaceous stem, like the morning-glory or the lady-slipper, dies at the end of the first season, the plant having produced its seeds. Other stems, like the trees, last year after year. Some of the redwood trees in California are known to be more than three thousand years old, and the Cedar of Lebanon, growing in Asia Minor, is known to live equally long.

STUDY OF WOODY STEMS

Draw a twig of horse-chestnut in winter condition. Label *rings* (scars of scales), *terminal bud* (on end), *lateral buds* (on sides), *leaf scar* (oval mark below bud), *vascular bundles* (on leaf scar). How many? How are the lateral buds arranged? Remove the scales carefully. Count and draw them. Describe them. What do you find inside? Draw and describe.

Compare with twigs of other trees — hickory, elm, maple, basswood. What differences do you notice?

337. External Appearance of Woody Stems. — If we take for an example a twig of the horse-chestnut, we shall find on the outside a brownish bark, some scars showing the position of last year's leaves, and some rings extending around the twig, indicating where the scales were attached that covered the bud containing these leaves. Above this scar will be found a bud covered with sticky scales, and at the end of the twig a large terminal bud.

The buds which grow above the leaves are called *axillary* buds. If more than one of these is found in an axil the additional ones are called *accessory* buds. The strength of the terminal bud determines the kind of branching of a trunk. A single very strong terminal bud gives the *excurrent* (Latin, *ex*, out; *curro*, run) trunk of the evergreen trees, and a

number of terminal buds of equal strength give the *deliquescent* (Latin, *de*, from; *liquescere*, to become liquid) branching of the elm and other trees. Between these extremes there are many intermediate forms.

The buds for next season's leaves are formed very soon after the leaves have reached their full size in the spring. Buds are protected in winter by coverings of scales which prevent them from becoming dry. A bud may contain leaves only, or flowers only, or both. Small markings on the smooth bark are *lenticels*, spots where the outer layer of the branch is broken, allowing air to enter the inner portions.

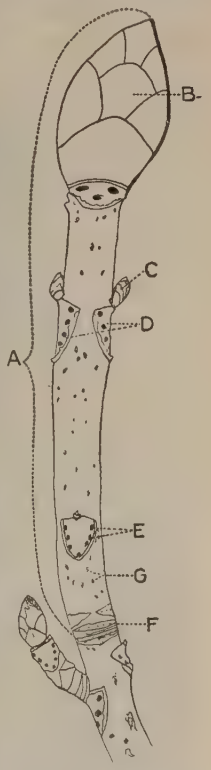

FIGURE 284. — TWIG OF HORSE-CHESTNUT.

A, growth made last season; *B*, terminal bud; *C*, lateral bud; *D*, leaf scars; *E*, fibro-vascular bundles; *F*, rings made by scales of last year's terminal bud; *G*, lenticels.

338. Tissues in a Woody Stem of Dicotyledon. — The study of a young woody stem shows not only the tissues of which it is composed but also the use which each one is to the stem and their relations to each other. The same kinds of relations can be seen in the tissues and cells which make up the organ of an animal. (See page 418.)

Pith, which occupies the center of a stem, is made up of large cells with thin walls. In the early stages of the plant's life, it serves as a place for the storage of food. Later it dies, and in an old stem often turns brown. Pith is smaller in an old stem than in a young one, as the woody layers crowd and compress it. Near the outside of the stem are the *fibro-vascular bundles*, which are the con-

ductive vessels of the plant. In a young stem, these lie in an incomplete ring with broad strips of pith between them. As the stem grows, more bundles develop between those already there, compressing the pith into narrow strips called

FIGURE 285. — EXCURRENT STEM (TRUNK) OF EVERGREEN.
The large trees in the foreground are redwood, probably hundreds of years old.

pith rays. These still serve to store food and to conduct water and other substances from the outer to the inner portions.

A fibro-vascular bundle in a woody stem is composed of three parts. On the inside is the *xylem*, consisting of thick-walled cells, and serving to convey water upwards. On the outside is the *phloem*, of larger thin-walled cells which serve to conduct prepared digested food downwards. Between the two is the narrow *cambium layer*, which is made up of small, thin-walled, regular brick-shaped cells. This is the region where growth takes place most rapidly. The brick-shaped cells on the inside of the cambium layer gradually change to the thick-walled xylem cells, and those on the phloem or outside of the bundle turn to larger, but still thin-walled phloem cells. As more and more bundles grow in the ring, the cambium layers touch and become a continuous ring. Thus it happens that a woody stem can add a layer of wood on the inside of the cambium, and a layer of phloem on the outside every year. It is easier to trace the woody rings, however, for they are protected and do not change, while the bark formed from the phloem cracks and falls off in bits, making it difficult to trace the annual rings.

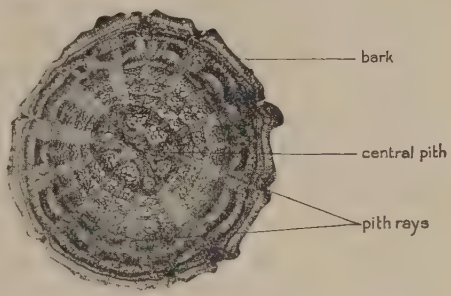

FIGURE 286. — CROSS SECTION OF YOUNG DICOTYLEDONOUS STEM.

The rays of pith between the fibro-vascular bundles of a young woody stem are gradually replaced by the medullary rays. These are woody cells of a special kind which arise from the cambium layer. Their function is to store food and

to form a connection between the cambium and the inner parts of the stem. Only the earliest ones formed extend to the pith. Later ones start in the cambium and extend into the wood for varying distances. The ones that extend to the pith are *primary* medullary rays, and the shorter ones *secondary* medullary or wood rays.

The bark of the older stem and the epidermis of a young stem are its protection against drying out, and against the attacks of insects as well as against the entrance of the spores of bacteria and fungi. Its porous structure also admits air to the interior of the stem. In the epidermis or the very thin bark of a stem are irregular openings called *lenticels*. These disappear as such when the bark becomes thick, but the air can still get in. All these parts, pith, woody portion, phloem, pith rays, and epidermis or bark combine to make up the stem, and at the same time each has a definite service to perform in the life of the whole plant.

339. Growth of Stems. — Most woody plants grow rapidly in the spring and early part of summer, after which they cease increasing in size but continue to add material which makes wood, thus enabling the stems to resist being killed in the winter. Such plants are said to have a *definite annual growth*. This is illustrated by most woody trees.

Other plants continue to grow until the end of the season. The latest formed wood in such plants is usually killed by the frost, with the buds on it. The plant begins to grow next season from axillary buds below the point where it was killed. Such plants are said to have *indefinite annual growth*. Examples are red raspberry and sumac.

Advantages of definite annual growth are twofold: (1) it enables a tree to grow very rapidly in the spring when conditions are most favorable for growth, and (2) it does not result in the loss of any wood once formed. On the other hand, the plant which makes an indefinite annual growth can take advantage of favorable growing conditions when-

ever they occur, although it may lose some of its youngest wood if frost comes before it is hard enough to resist it.

In the annual growth of woody stems, a new node is added to each branch, and a new layer of wood over the wood of previous years. This makes it possible to tell approximately how many years old a tree is, the growth of each year forming a ring more or less distinct according to conditions. When the conditions for growth are at their best, the cells formed are large. As conditions become less favorable, the cells become smaller and have thicker walls, marking distinctly the end of one season's growth from the beginning of the next. The size of the cells varies greatly in different trees, producing the "grains" which are so characteristic of each kind of lumber.

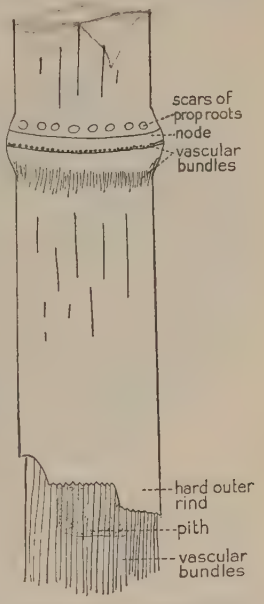

FIGURE 287. — BROKEN END OF CORN STEM.

340. Monocotyledonous Stems. — In the corn stalk, a monocotyledonous stem, the vascular bundles are scattered throughout the central pith, and the bundles have no definite position with reference to the center. The outside of the stem is covered with a hard rind which often contains silica, a substance like glass which makes it hard and strong. In grasses, the stem is hollow, and the bundles are of course around the edges, some of them passing off at each node into the leaf which arises from it.

341. Tissues in Monocotyledonous Stems. — A vascular bundle in a monocotyledonous plant is made up of two kinds of cells or groups of cells called *xylem* (zy'lĕm) and *phloem* (flō'ĕm). The xylem cells are thick-walled, but with thin spots in each cell where it touches another cell of the same

kind. Each cell is long and pointed. Some of these cells overlap in such a way that they make continuous tubes from the root, up through the stem, and into the leaves. The thick walls help to give firmness to the plant.

The phloem cells are the other part of the vascular bundle in a monocotyledonous stem. They have thinner walls than the xylem cells and they communicate with one another through the ends and not through the sides. The ends of these cells have perforated plates through which the liquid in the cells passes. These are called *sieve plates*.

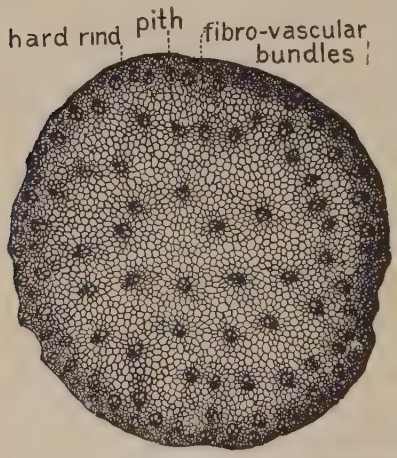

FIGURE 288. — CROSS SECTION OF MONOCOTYLEDONOUS STEM.
Showing scattered fibro-vascular bundles.

342. The Work of the Vascular Bundle. — We have said that the vascular bundles are a part of the conductive system of a plant, and that some of the cells form vessels. There is little likeness to the vascular system of animals, however, for the system in plants lacks an organ for driving the liquid in the tubes, and it has little use as an aid to respiration. Water, absorbed from the soil by the root hairs, is passed by osmosis to the slender cells in the roots, and from there *up* through the stem and to the leaves, where it is used in photosynthesis. After the food made by photosynthesis is digested and thereby made ready for the use of the plant, some of it is carried *down* through the phloem part of the vascular bundle to such parts of the plant as need it. There is in this a likeness to the circulation of animals in which

fresh blood is carried in one set of vessels and blood that needs renewing in another set. The liquid which is carried in the vessels of plants is commonly called sap, and when a plant is broken, and the sap oozes out, we speak of it as bleeding.

HOME WORK — STEMS

1. Examine the house you live in to learn, if possible, the kinds of lumber used for the floors, for the casings, and for the doors. What kinds do you like best? Why?
2. Examine all the wooden furniture and answer the same questions.
3. Examine the different kinds of matting. Of what is each made? Examine linoleum. Of what is it made?
4. Examine the wicker furniture. Of what is it made? What is rattan? bamboo?
5. Examine your "straw" hat. Of what is it made? How?
6. Examine the doormat. Was it made from any part of the stem of a plant?
7. Examine the clothes-basket and the market-basket, and the sewing-basket, and try to decide from what each was made.
8. Examine a trunk, a box, a barrel, a pail, a picture-frame, a harness, a wagon, an automobile, a fence, telegraph poles, paving blocks, corks, and toys of various kinds, to find what parts of them are made from wood, and what kinds of wood are used.
9. Make a list of all the other things, as spools, that are made of wood.
10. What substitutes for wood do you find? In what respects are they better? in what respects inferior to wood?
11. How is paper made?
12. What is celluloid?
13. Where is thatch used?
14. What is oakum? In what industry is it used?
15. Why is excelsior a good material for packing fragile articles?
16. Into which of your garments does linen enter?
17. What is jute? manila? burlap?
18. How many trees do you know? Which do you like best? Why?

343. Practical Applications — Stems as a Means of Propagating Plants. — Stems are used in various ways in propagating plants. "Slipping" plants is a common prac-

tice, the success of which is due to the fact that adventitious roots grow readily from the cut end of a branch of geranium, balsam, ivy, and other plants. Two advantages make slipping popular: (1) the certainty of securing a new plant like the parent plant, (2) the short time required to produce blooms compared with that for the same kind of plant raised from the seed. Willow twigs root so readily that it is often possible to start a hedge by sticking pieces of branches into the ground when it is very wet.

Grafting. — (See page 10.) Grafting is a common method of propagating trees. It depends for success upon putting the cambium layer of a twig from one plant against the cambium of another and fastening it there until the two layers have grown together, protecting it from moisture, insects, and fungi by a layer of wax. Usually a twig from a mature tree (the scion) is grafted upon the young stem of a seedling or on an inferior tree (the stock), producing fruit several years earlier than the seedling tree would. One can be sure, too, of obtaining the fruit wanted. If twigs from several kinds of trees be grafted upon a " scrub " tree, each twig will bear its own kind of fruit. The pome fruits, drupe fruits, and citrus fruits are usually grafted. Greenhouse roses, azaleas, and other plants are propagated in this way.

Budding. — Budding is a process similar to grafting except that a bud is slipped into an incision in the bark, instead of a twig being inserted into the end of a branch. (See page 9.)

Layering. — Layering is a method of obtaining new plants by covering a branch with earth some distance from its tip. When roots form, the branch is severed from the main plant and transplanted. Roses, grapes, and currants are propagated by layering. All these methods are artificial, and seldom found in nature.

Pruning. — Pruning is advisable for the following reasons: (1) to make the tree a better shape and to remove superfluous

branches and those not well situated to bear fruit; (2) to remove broken or dead branches; (3) to make the sap form fruit instead of new vines or branches.

Pruning should be done carefully. Branches should be sawed off smoothly as close to the trunk as possible. This will enable the wounds to heal more quickly and be less unsightly. Healing is accomplished by the growth of a special kind of tissue which forms from the ring of exposed cambium and grows inward.

When a branch is sawed off, the wound should be covered with paint at once to prevent the entrance of bacteria and spores of fungi.

Pruning should not be done when the sap is running freely, for bleeding weakens the tree or vine.

Girdling. — When a tree is "girdled" with the purpose of killing it, the cut must be deep enough to reach and destroy both xylem and phloem. If only the phloem vessels are cut, the tree will continue to grow above the incision, since water can ascend through the uninjured xylem vessels to the leaves. If the supply of water is stopped by cutting out all round the

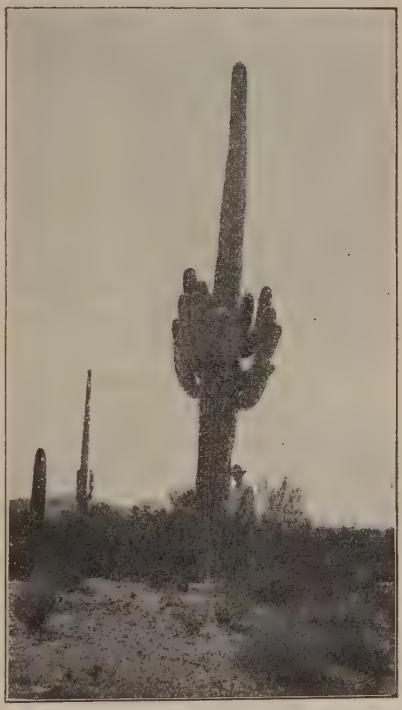

FIGURE 289. — GIANT CACTUS.
The stem is adapted to perform photosynthesis and to reduce transpiration.

tree a section of the xylem vessels which carry it up, wilting will soon take place owing to the continued loss from transpiration. The manufacture of food will cease on account of the lack of water, and the tree will die. When young trees are girdled by rabbits, as sometimes happens in winter, the space can be filled in with split twigs carefully adjusted as in a graft, and growth will continue.

344. Specialized Stems. — In regions where the climate is very hot and dry most of the year, the leaf surface is greatly reduced to prevent undue evaporation. In this case the stem becomes green and performs the work of photosynthesis (see page 477), ordinarily done by leaves. The cactus illustrates this. Certain other plants have no leaves, but the stem branches in such a way as to resemble leaves. The florist's smilax and asparagus fern represent this kind of branching. The true leaves are reduced to minute scales.

LABORATORY STUDY OF STEMS

Draw a potato. Label the "eyes" *buds*. On which end are they more numerous? Label *scale*, just below *bud*. Note end where it was attached to the main plant.

Cut off the stem end and stand in water colored with red ink. After two hours examine again and note what part is stained. Cut off slices till traces of color disappear. Draw to show where it is colored. Cut a thin slice and put a few drops of weak iodine on it. What happens? What does it show?

Cut an onion bulb vertically. Note the condensed stem on which the leaves are arranged.

345. Underground Stems. — An underground stem can always be distinguished from a root by the buds of new leaves or the scales of old ones, although in some the leaves are reduced to mere scales, as in the potato. Underground stems usually send up aërial shoots. They often have an advantage over an aërial stem in being better protected. Some plants make use of the underground stem in propagating themselves.

Canada thistles, quack grass, and devil's paint-brush are among the most difficult of weeds to eradicate, owing to their branching, underground stems, each piece of which, when broken off by cultivation, forms a new plant. Dandelions, because of their greatly reduced stems, are not easily killed by trampling. In digging dandelions from lawns, care must be taken to cut deeply enough to remove the whole crown of the plant, otherwise the injured stem branches and forms a weed more troublesome than the original one.

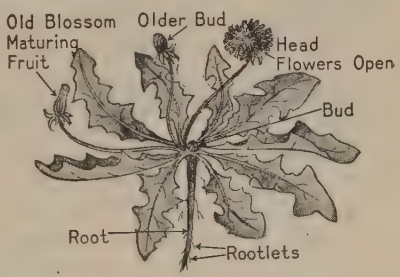

FIGURE 290. — DANDELION.
This plant has no visible stem.

Bulbs. — The bulb, a common form of underground stem, has a somewhat flat and disc-like appearance. The roots sprout from the under side, and above are found tightly compressed, fleshy leaves. The hyacinth and the onion are examples.

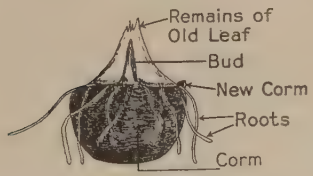

FIGURE 291. — CORM OF INDIAN TURNIP.
This shrivels as the stored starch is used by the growing plant.

Corms. — In appearance corms resemble bulbs but, contrary to the leafy structure of bulbs, corms are solid, fleshy stems with the leaves and buds growing from the upper surface and the roots from the lower, as for instance in the cyclamen. In some corms, such as the crocus, there is an outer covering or sheath of one or two leaves which causes them to be given the name of solid bulbs.

Tubers. — A tuber is usually round or oblong and consists of a branch-like body which is much thickened and which

has many "eyes," the modified axillary buds. Usually some of these buds produce a new plant the next season, the nourishment for which is stored in the form of starch in the tuber. The potato illustrates this variety of underground stem.

FIGURE 292. Grains of potato starch, highly magnified.

Rhizomes. — This stem has a root-like appearance. It may be found lying on the ground or under ground. It has scales instead of leaves. At its apex grows a leafy shoot. Rhizomes vary in structure. They are sometimes slender with the nodes plainly visible, sometimes thick and solid-looking, having the nourishment stored in them for the new plant. Mints are examples of the former, Solomon's seal of the latter variety.

346. Stolons. — Other plants propagate themselves by stems naturally, as the strawberry, which puts out long, leafless branches called stolons or runners, each stolon having a bud on the end which takes root when it finds favorable conditions, especially contact with the soil. When a new plant is well established the stolon ceases to carry nourishment from the parent plant and soon dies. Black raspberries produce long, drooping stems which have buds on the ends similar to those on the stolons of strawberries. New plants are formed when these rest on the earth, several sometimes arising from the branching end of a parent plant, from which it later becomes separated.

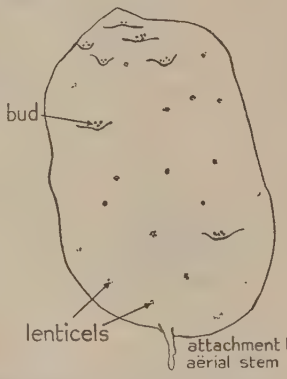

FIGURE 293. — POTATO, A COMMON TUBER. A form of underground fern used for storing food, chiefly starch.

A large garden lily has a method of propagating itself that is not common, namely by bulblike growths produced in the axils of the leaves.

LABORATORY STUDY: COURSE OF SAP

Place a living pea seedling in water containing eosin. If possible, use one that has been germinated in sawdust in a paper cup. Make a hole in the bottom of the cup, and set it into a tumbler of water containing eosin or red ink. After two or three hours note the presence of eosin in the stems and leaves. Repeat the experiment, using a seedling that has been grown in the dark. Compare with one that has been grown in the light.

Stand twigs of apple, maple, elm, and other trees in water colored with red ink or eosin. Examine after two hours, also after standing overnight. Split the twigs lengthwise, and cut the ends squarely and obliquely, to see the path taken by the colored water.

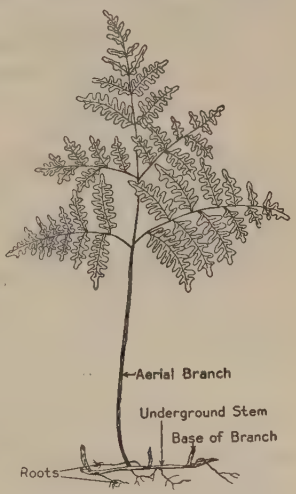

FIGURE 294. — RHIZOME OF PTERIS, A COMMON FERN.

347. Uses of the Stem to Man. — Man makes use of the stem for food, the potato being one of the most familiar as well as important examples of such use. Starch is also made from potatoes. The stem and buds of asparagus are used for food.

A second use is for shelter. Trees furnish lumber in all its varieties. Some parts of houses can be made from stone, brick, or other materials, but for the inside finishing we are still dependent upon wood.

A third use is for furniture. No other material has been found that is so satisfactory as wood for tables and chairs.

A fourth use is for clothing. The flax plant which furnishes the material from which linen is made is one of the most

valuable. Its usefulness depends upon the bast fibers which it contains. These are found in the outer part of the slender stem and serve to give it stiffness. When separated from the other parts of the stem they can be twisted, spun, and woven.

Fifth, the stems as well as the leaves of peppermint, boneset, wormwood, catnip, foxglove, and other plants are used as medicine.

A sixth use is for cordage. This includes all kinds of ropes and many kinds of strings. Some cordage is obtained from fibers of hemp, and some from other plants.

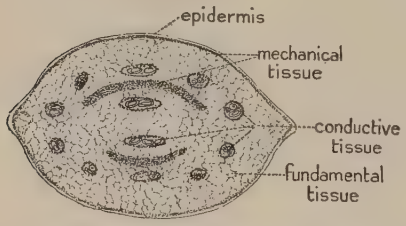

FIGURE 295. — CROSS SECTION OF UNDERGROUND STEM OF PTERIS, A COMMON FERN.

Seventh, in many places wood used as fuel is the only source of heat for cooking and keeping warm in winter.

Among the many other uses of stems in our daily life may be mentioned poles for telegraph, telephone, and electric light wires, for the masts of ships, for the piles of piers, timbers for props of mines, lumber for bridge foundations, cross ties of railroads, besides parts of implements and tools of daily use, vehicles and parts of machines by which many of these are made. Add to these the boxes, barrels, crates, trunks, pails, baskets, and other common articles which we use frequently, and paper in its many forms and numerous uses. It is evident from this list, which is far from complete, that man has found the stems of plants to be of great use to him, and that he could not well do without them.

Adaptations of Wood. — When we compare the number of articles that are made of wood with the same articles made of substitutes, we see that there are some good reasons for the use of wood. Among these are its *lightness* compared with

iron or steel for use in furniture, trunks, and other articles, its *elasticity*, its *toughness*, its *durability*, especially when protected from dampness, the *ease* with which it can be shaped by tools, and its *beauty*, depending on color and grain, and on the high polish it can take.

OUTLINE

- Kinds of stems
  - Monocotyledonous
  - Dicotyledonous
- Functions
  - Support
    - For plant
    - For leaves
  - Water carrier
  - Food storage
- Position
  - Upright
  - Trailing
- Duration
  - One year
  - Three thousand years
- Appearance
  - Scars
  - Buds
    - Axillary
      - Accessory
    - Terminal
      - Excurrent
      - Deliquescent
- Dicotyledon
  - Pith
    - Pith rays
  - Fibro-vascular bundles
  - Xylem
  - Cambium layer
  - Phloem
    - Bark
  - Medullary rays
    - Wood rays
- Growth
  - Annual
    - Definite
    - Indefinite
- Monocotyledon
  - Vascular bundles
  - Xylem
  - Phloem
  - Sieve plates
  - Work
  - Applications
  - Grafting
    - Budding
    - Layering
    - Pruning
    - Girdling
- Specialized stems
  - Cactus
  - Smilax
- Underground stems
  - Bulbs
  - Corms
  - Tubers
  - Rhizomes
- Stolons
- Uses of stems
  - Food
  - Shelter
  - Furniture
  - Clothing
  - Medicine
  - Fuel

SUMMARY

The stem is the part of the plant which forms the connection between the roots, which gather food materials, and the leaves, where food is manufactured. It is compact and sturdy because it must bear the weight of the leaves and branches, and because the vessels through which liquids are conducted in it must be well protected. Most stems grow above ground and upright, but some lie on the surface of the ground, and some below the soil. The stem of the woody plants is employed by man in more ways than any other part, furnishing him shelter, fuel, furniture, clothing, paper, parts of many machines and implements on which he is daily dependent. Stems are a source of some food for man and the stems of the grasses furnish food for many animals.

QUESTIONS

What is the stem? What is its use to the plant? What positions do stems take? How long do they live? Name and describe the peculiar stems. What are vascular bundles? How are they arranged in a monocotyledonous stem? In a dicotyledonous stem? What is their work? What is meant by definite annual growth? Indefinite annual growth? What are annual rings? How are they formed?

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Bergen and Caldwell, Practical Botany, pages 11–13, 39–103.
Coulter, Plant Life and Plant Uses, pages 49 and 143–193.
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Snyder, General Science, page 188.

CHAPTER XXIX

THE ROOT, THE PLANT'S ABSORBING ORGAN AND ANCHOR

The bended twigs take root, and daughters grow
About the mother tree, a pillar'd shade
High overarch'd and echoing walks between.

— Milton

348. Structure of Roots. — The outer part of the primary root is covered with a layer of epidermis which acts as a protection layer. Inside of this is a region called the *cortex* which surrounds the central cylinder. Near the tip at the farther end of the central cylinder is the main growing region from which the epidermis, the cortex, and the central cylinder are formed. At the tip end of the root is a root cap which is the protective tip for the growing root.

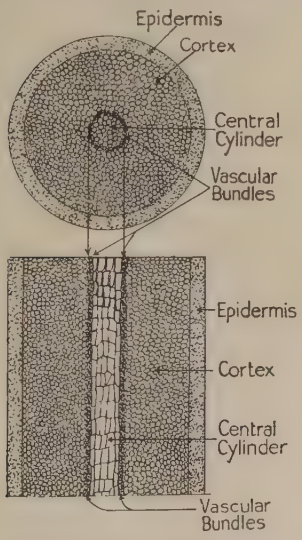


Figure 296. — Cross and Longitudinal Section of Root.

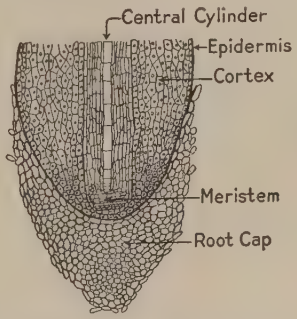


Figure 297. — Vertical Section of Root.
The meristem is the growing region.

The secondary roots which branch off the main roots start from the central cylinder. Each of these parts of a root adapts it to do its work. The epidermis keeps it from drying. The region of the central cylinder contains the conducting vessels which carry water to the stem and digested food back. The cortex is the region in which most of the food is stored.

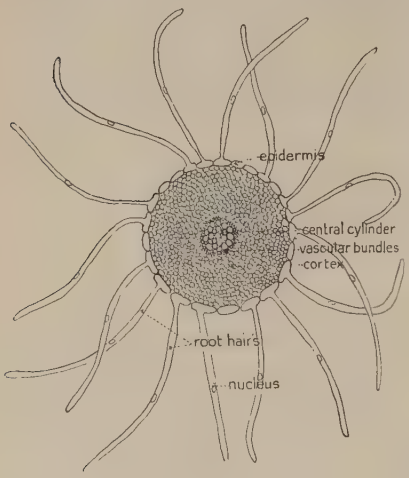


Figure 298. — Cross Section of Root with Root Hairs.

These were grown in moist air. Compare with those grown in soil.

The root cap protects the tender end of the root from injury as it pushes through the soil, and the growing tip provides for renewing all the regions of the root and increasing their size.

Besides the main root, there are many smaller roots which divide still further into rootlets. The root and its divisions

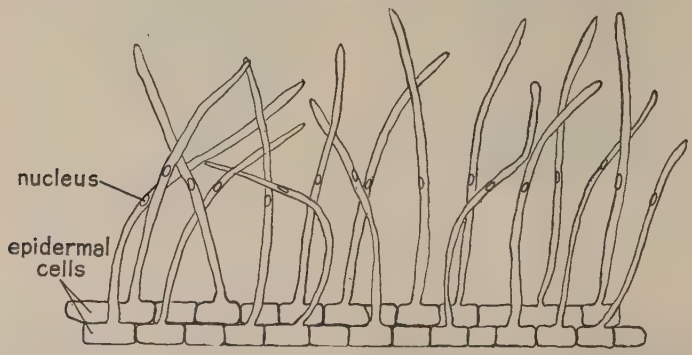


Figure 299. — Bit of Epidermis of Root, Showing Origin of Root Hairs.

underground may be compared, in a general way, to the stem, branches, and twigs above ground.

349. Root Hairs. — Root hairs are found a short distance back from the tip of each rootlet. Each hair consists of a projection of an epidermal cell. Root hairs are very numerous. As the root grows, the hairs farthest from the tip die and are replaced by new ones nearer the tip. Root hairs greatly increase the absorbing surface of a rootlet. They attach themselves firmly to particles of soil from which they take almost every trace of moisture by osmosis (see page 42). They also serve to fix the plant firmly in the soil.

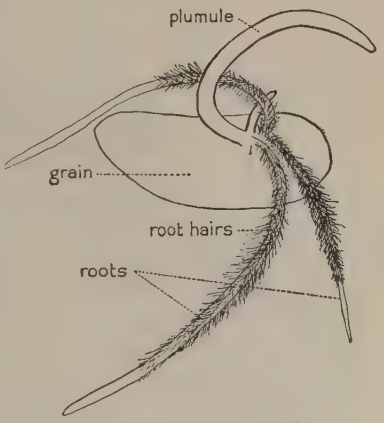


FIGURE 300. — GERMINATING WHEAT, SHOWING ROOT HAIRS.

Notice the plumule growing up and the roots down. This grain of wheat was germinated in moist air, and not in the soil. Root hairs are seldom seen in soil-grown seedlings, as they are so fragile that they break off and remain in the soil when the seedling is removed.

LABORATORY STUDY OF ROOTS

(*a*) Cut a root of carrot or parsnip lengthwise and identify (1) the epidermal covering; (2) *cortex*, the region under the epidermis; (3) *central cylinder*. Cut it crosswise and identify the same regions. Make drawings of both sections and label fully. In both sections look for rootlets and note the region from which they arise. Show this in your drawing.

(*b*) Examine a root hair to determine its structure. Of how many cells is it composed? From what does it develop?

In a vertical section of a root note the root cap. What is its structure? Its use? Where is the region of growth?

(*c*) Make a cut through the root of a Tradescantia (wandering Jew) and observe the various parts, especially the root cap.

350. Primary Functions and Forms of Roots. — Roots are the part of the plant that (1) gather water and food material from the soil; (2) hold the plant firmly in the soil;

FIGURE 301. — ROOT SYSTEM OF RHUBARB, A MEDICINAL PLANT. Food is stored in the larger parts. Note many secondary roots. Many of the rootlets have been broken off.

and (3) in plants that live over the winter, store food to be used the following year.

Tap or *primary roots* are the first ones formed in many plants. Secondary roots branch from the primary. Both

are adapted to penetrate the soil deeply, enabling them to secure water when plants with different roots cannot. They are adapted also to the storage of food.

Fibrous roots are the many thread-like roots which extend in all directions through the soil.

Thickened fibrous roots are a modification of fibrous.

Fascicled roots are a cluster of thickened roots for the storage of food.

Some plants like the ivy have *aërial roots* for attachment. Note how they grow from side of stem. Aërial roots may also absorb water, as in the case of certain orchids, tropical plants which grow in the air.

Water roots lack a root cap. The duckweed is an illustration of this.

Knees are the projections on roots, as in the cypress.

Adventitious roots are those that grow in unusual positions, especially from the end of a cut stem as in the geranium, willow, or any "slip."

FIGURE 302. — FIBROUS ROOTS OF A BUTTERCUP (slightly thickened).

351. The Duration of Roots. — Roots which live only for a season are called annual roots, examples of which are corn, peas, beans, and other common garden plants. Those that store the food manufactured one season and use it to produce flowers and fruit the next are called biennial roots. The garden furnishes examples of these in the fleshy roots of carrots, parsnips, beets, turnips, and vegetable oysters. Roots that live from year to year, like those of trees, the dandelion, bur-

dock, horse-radish, peony, and "pie plant," are perennial roots.

352. Extent of Root System. — The root system of a tree growing in fertile soil is about equal to the parts above the ground. An oat plant has a root system the combined length of which is about 154 feet; a wheat plant has single roots seven feet long; and alfalfa an enormous root system. A single root of alfalfa may extend more than 20 feet in one direction in a loose soil.

FIGURE 303. — FASCICLED ROOTS OF DAHLIA.

Fascicled roots occur in clusters. They are used for the storage of food.

353. Specialized Roots. — The roots of the ivy which grow for attachment differ from ordinary roots not only in their function, but in their position. They can grow from any side of a stem, enabling them to attach themselves to a surface wherever they may happen to touch it.

The haustoria by which parasite plants get their food from the host are modified aërial roots. They are able to take food from the stem of the host by absorbing pads, as is well illustrated by dodder.

The cypress tree, which grows with its roots submerged, has peculiar projections which extend above the surface of

the water. These so-called "knees" are so modified that the roots are enabled to secure the air they need.

The pendant roots of the tropical orchids, known as velamens, have a modified outside layer which enables them to absorb almost immediately any water which falls on them

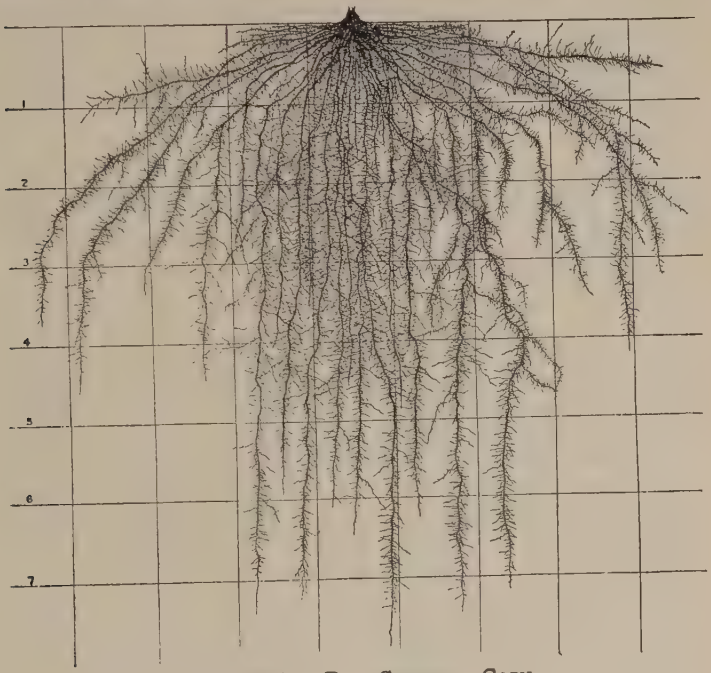


FIGURE 304. — ROOT SYSTEM OF CORN.
Near the end of the growing season.

and conduct it to the central cylinder for storage. This enables the plants possessing them to live outside of the soil successfully.

Prop roots of corn grow from nodes above the soil, which they penetrate. This is an adaptation for holding the plant more securely than the ordinary roots could do. When mature, they branch freely.

Adventitious roots are those which grow from unusual places, especially soil roots. It is the ability to form such roots that enables us to " slip " plants like geraniums, balsams, ivy, and wandering Jew. Such garden plants as tomato, cucumber, squash, and others, put forth adventitious roots where their stems touch the soil, especially at the nodes in the case of the vines named. This is an adaptation which gives them a greater supply of food material near the leaves which use it, and which enables the plant to live even if broken from the main portion of the stem.

Certain cactus plants which live in the desert have roots which are twenty times as long as the parts which appear above the soil. This enables them to absorb and to store up the scanty moisture.

LABORATORY STUDY

Osmosis Experiments. — Prepare an egg for a demonstration of osmosis. (See page 42.) When the usual demonstration is completed, remove the tube, break the upper part of the shell, and empty contents. Fill the shell half full of clear water, distilled or from the tap, and set it in a beaker containing sugar and water. After four or five hours note (1) increase in amount of water in the beaker, and (2) decrease in the amount of water in the shell. Account for what you find.

Place a filament of spirogyra in strong salt and water and observe what takes place, using the high power of a compound microscope. Note that the protoplasm shrinks from the wall of each cell, and becomes more condensed. Draw out the salt water and replace with distilled water, and observe again. After a few minutes the cytoplasm again fills the cell wall. Account for what you have observed.

Demonstration to Show Region through Which Liquids Rise.— Stand cut-off roots of parsnip overnight in water tinted with red ink. In what region does the color show? Make cross sections of one and longitudinal sections of the other. Draw both and describe.

Look at the roots of seedlings furnished you. How does the extent of roots compare with the parts above ground?

Examine roots grown in a moist chamber for root hairs. Compare with one grown in sawdust or soil after it has been carefully washed.

How do they differ? On what part of the rootlet are the root hairs most numerous? Where are they the longest?

Mark a root with a fine pen dipped in India ink, making the marks even and close together (about 1 mm.). Examine from time to time to determine where growth is most rapid as shown by increased distances between marks.

Tests for Foods. — Test roots for the presence of starch, sugar, and protein, using the tests suggested for seeds, page 537. Make a report on what you find.

In what direction do roots usually grow? Try to make them grow in some other direction. Write what you did and show by drawings what success you had.

Draw aërial roots of an ivy stem.

Draw a cluster of fascicled roots of a dahlia or a buttercup or an anemonella.

Demonstration to Show the Response of Roots to Moisture. — Fill a funnel with sawdust and soak it thoroughly. Wrap it with sheets of blotting paper. Fit a ring of cork into the top of the funnel. Fasten to this a number of seedlings with short roots, taking pains to have them extend along the ring, over the sawdust, and over the edge. Place the funnel in a dish of water to keep the sawdust and the blotting paper moist. After four or five days examine to see what changes have taken place in the position of the roots. Have any left the cork ring and entered the sawdust? Have any bent over the edge to get to the wet blotting paper? Have any died because they could not get water? What experiment can you devise that will serve as a check on this demonstration?

SUGGESTIONS FOR HOME WORK

Pull weeds and examine the roots. Which have tap roots? Why do they flourish better than the plants around them?

Cut a piece of thick sod with a sharp spade or trowel. How many grass plants in a square two inches on a side? What kinds of roots has grass? Wash the dirt away carefully and measure the extent of the root system. Compare it with the part above ground. Do the same with other plants than grass.

On how many nodes of a corn stem do prop roots grow? What is the effect of "hilling up" corn on the production of prop roots?

Place willow twigs in water. Watch the growth of adventitious roots, noting especially the root caps. Do duckweed and other floating plants have root caps? Account for what you find.

Examine a large number of roots and report.

	Roots All Underground	Roots not All Underground	Primary Roots	Fibrous Roots	Aërial Roots
Dandelion					
Plantain					
Carrot					
Dahlia					
Corn					
Ivy					

354. Uses of Roots to Man. — In some plants the root is the most valuable part for food not only for man but also for his animals. Examples of this are found in many of the garden vegetables, such as carrot, parsnip, turnip, vegetable oyster, and beet. The food stored in the beet is rich in sugar, making it one of the sources of the sugar of commerce as well as a valuable food for stock. Other roots furnish substances used as medicine when they have been extracted, as rhubarb and mandrake, while the ground root of ginger is used in medicine and in cooking. The vegetable oyster is often found growing by roadsides, where its seed has been blown from gardens.

In the case of these roots, a few must always be saved to produce seeds for another crop, inasmuch as turnips, beets, carrots, parsnips, and vegetable oysters are biennials, requiring to be planted the second season, when they use food stored during the first year to produce fruit and seeds.

OUTLINE

- Structure of roots
  - Central cylinder
  - Cortex
  - Epidermis
  - Root cap
  - Root hairs
- Functions
  - Gather food
  - Hold firm
  - Store food
- Forms
  - Tap
  - Fibrous
    - Thickened

- Fascicled
- Water roots
  - Knees
- Adventitious roots

Duration

- Annual
- Biennial
- Perennial

Extent

- Specialized roots
  - Aërial
  - Submerged
  - Pendant
  - Prop

Uses

- Food
- Medicine
- Propagation

SUMMARY

The root is the part of the plant that grows in the soil to gather water and food materials for it, to hold it securely, and to store food for it. Roots have many forms, the primary or tap root and the fibrous roots being the extremes. Small roots have a root cap to prevent injury to their tips, and root hairs to increase their absorbing surface. There are specialized roots for special purposes, such as aërial roots for support and for gathering water. Adventitious roots are those that grow on "slips." Roots form an important part of man's food, and food for his animals.

QUESTIONS

What is the root? What does it do for the plant? Describe the structure of a tap root. How do fibrous roots differ from a tap root? In which kind of roots is most food stored? What use does the plant make of this stored food? What use does man make? What kinds of food are stored in roots?

REFERENCES

Bergen, Foundations of Botany, pages 62–129.
Bergen and Caldwell, Practical Botany, pages 5–16, 24–38.
Conn, Biology, page 112.

CHAPTER XXX

FLOWERS AND FRUITS

Mourn, little harebells, o'er the lea;
Ye stately foxgloves fair to see!
Ye woodbines hanging bonnilie
In scented bowers!
Ye roses on your thorny tree,
The first o' flowers.

— BURNS

355. Introduction. — The plants we all know and like best are those that at some time in their lives produce beautiful flowers. These flowers, however, are only temporary structures which drop off as soon as their work is done. They are the special adaptations of the plant for producing more plants. A flower is simply a modified branch, the parts being modified leaves. Some flowers, for example the water lily, show this plainly at all times, and others show it only under certain conditions, as in the case of the rose.

356. Structure of the Parts of a Flower. — The parts of a flower are best studied in some particular plant. The following are the parts as found in the nasturtium:

Sepals (Latin, *separ*, separate). — These are greenish, pointed, leaf-like parts on the outside of the flower. Together they make up the *calyx* (Greek, *kalyx*, cover), which protects the rest of the flower, at least while it is in the bud, from insects, cold, rain, etc. One of the sepals has a spur, in the bottom of which is a drop of nectar.

Petals (Greek, *petalon*, leaf). — The larger parts, more showy because more brightly colored, are *petals*, which taken together make up the *corolla* (Latin, *corolla*, crown).

Stamens (Latin, *sto*, stand). — These are the slender organs which surround the most central portion of the flower. The stamen has two parts, the *filament* or stalk, and the *anther* or box at the top, which contains the pollen.

Pistil. — The central portion of the nasturtium is the pistil, made up of three parts. At the top is (1) the stigma (Greek, *stigma*, point); below it (2) the style (Greek, *stylos*, pillar) which connects it with the lowest part, (3) the ovary (Latin, *ovum*, egg).

The sepals and the petals are sometimes spoken of as floral envelopes or as *accessory parts*, in distinction to the stamens and the pistil, the *essential parts*. Only the latter are necessary for the production of seeds. The nasturtium is a *perfect* flower because it has the parts necessary for the production of seeds, and it is a *complete* flower because it has also the accessory parts.

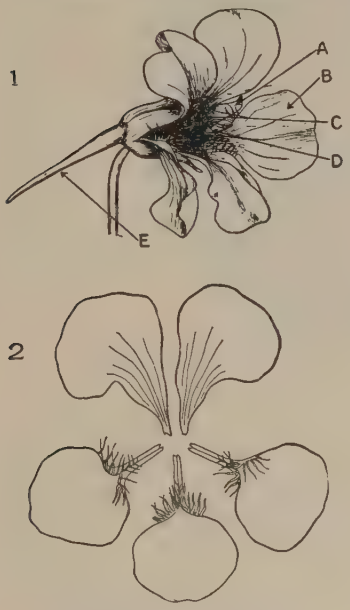


FIGURE 305. — FLOWER OF NASTURTIUM.

1. whole flower. *A*, sepal; *B*, petal; *C*, stamens; *D*, pistil; *E*, spur. 2. petals.

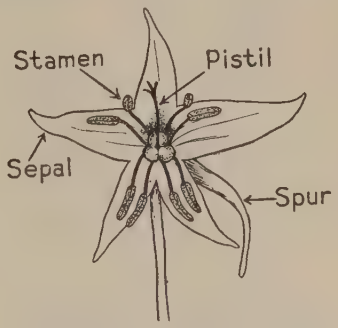


FIGURE 306. — FLOWER OF NASTURTIUM WITH PETALS REMOVED.

Besides the four sets of parts found in nasturtium flowers, other parts will be found in certain flowers, the *receptacle*, for example, the expanded top of the stalk on which the floral organs are placed. This is sometimes oval as in buttercups, or large and fleshy as in strawberries, or hollow as in the rose, where the pistils arise from its inner surface. The *crown* is a projection growing from the surface of a petal as in narcissus. The *spur* already mentioned is another modification of a petal or a sepal. Violets, snapdragons, toad flax, and larkspur have spurs. Nectar glands, usually found near the base of a flower, are commonly found in those flowers which are adapted to attract insects.

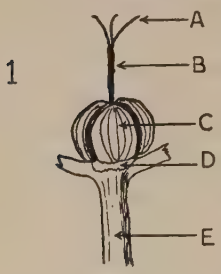


FIGURE 307. — PISTIL AND STAMEN OF NASTURTIUM.

1. *A*, 3-parted stigma; *B*, style; C, 3-parted ovary; *D*, receptacle; *E*, peduncle.

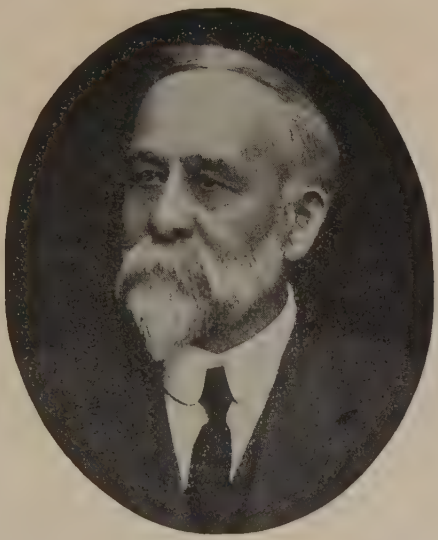
2. *A*, anther, with pollen; *B*, filament.

LABORATORY STUDY OF A NASTURTIUM

Provide each pupil with a nasturtium flower. Draw the flower, and label the parts as follows: (1) *sepals*, the outermost, greenish parts; (2) *petals*, the colored, larger parts; (3) *stamens*, the slender parts inside the petals; (4) *pistil*, the central part of the flower; (5) *spur*, the projection on one of the sepals; (6) *peduncle*, the flower stalk.

How many sepals are there? Are they all the same size and shape? How many petals are there? Are they all the same size and shape? Have they all furrows, or streaks of color leading to the base of the flower? If not, which ones have one or the other? Which ones have a hairy fringe on the inside? Do the hairs all point in the same direction? Open the end of the spur and taste the liquid. Describe the taste.

How many stamens are there? Draw one and label (1) *filament*, the slender, stalk-like part; (2) *anther*, the enlarged top which contains yellow, dust-like particles, the *pollen*. If possible, examine pollen grains with a microscope. Describe them.



Charles Edwin Bessey was born in Milton Township, Wayne County, Ohio, May 21, 1845, and died at Lincoln, Nebraska, February 25, 1915.

He was educated in the country schools and academy, and at the Michigan Agricultural College, from which he graduated in 1869. In February, 1870, he began his duties as Professor of Botany at the Iowa State College at Ames, Iowa. In addition to botany, he taught zoölogy and entomology for the larger portion of the fifteen years that he remained at that institution. He assumed the professorship of botany at the University of Nebraska in November, 1884, a position held by him until his death.

His greatest contributions to botany are: the introduction of the laboratory method in teaching the science; his enrichment of the whole field of botany by teaching many new aspects of the subject; and his profound influence upon students and future investigators.

Draw the pistil. Label (1) *stigma*, the top portion; (2) *style*, the slender part below the stigma; (3) *ovary*, the enlarged base. Examine the stigma with a hand lens. Does it appear sticky? Can you see pollen grains on it? Cut across the ovary. How many chambers has it? How many *ovules* (small, white bodies) are in each chamber? Draw and label.

Examine a nasturtium blossom that has stood in water till it has withered. What parts of the flower have dried up? Which ones have fallen off? What parts remain? What changes have taken place in those that are left?

FIGURE 308. — LONG-SPURRED BLUE VIOLET.
All violets have an irregular corolla.

SUGGESTIONS FOR HOME WORK

Compare any blossoms you have at home with the nasturtium (geranium is a good one). Do you see any indications of irregularity in the geranium? Of a spur? Of colors or furrows on the petals? Examine other flowers in the same way — apple, violet, lilac, chickweed, etc. Make notes and sketches of what you find out for yourself, and of questions that occur to you.

357. Structure of the Lily. — So important are these parts of the flower that it is well to review them in another flower, the lily. Here the *pistil* is the central organ and has three parts, (1) the expanded, sticky *stigma* at the top, (2) the *style*,

the long, slender connecting portion, and (3) the *ovary*, the expanded base. Inside the ovary are the *ovules*, which contain the egg cells from each of which an embryo plant will develop if it becomes fertilized. The part of the ovary to which the ovules are attached and through which they get their food is the *placenta*. The *stamens* are the parts of the flower outside of the pistil and surrounding it. Each stamen consists of a slender stalk, the *filament*, and an *anther*, the part which contains the pollen. Around the outside of the stamens and pistil are the colored parts which together form the perianth of the flower (Greek, *peri*, around, *anthos*, a flower). In the lily the perianth consists of six parts of the same color, size, and shape. Because of the even size and regular shape of the parts of the perianth of the lily, we speak of it as a *regular* flower. The perianth is an *accessory* part of the flower, for seeds can be made without it, the stamens and the pistil being the only *essential* parts.

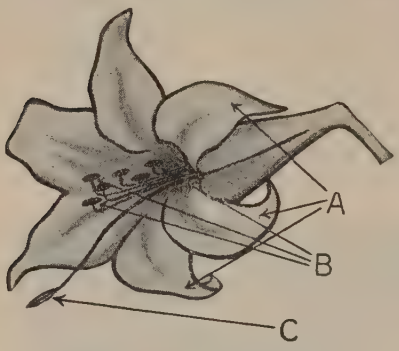


FIGURE 309. — FLOWER OF LILY.
A, divisions of perianth; B, stamens; *C*, pistil.

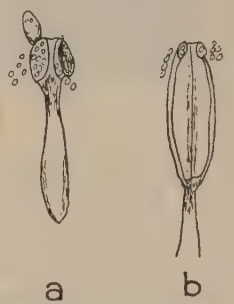


FIGURE 310. — STAMENS.
a, pollen shed by lifting of lid; *b*, pollen shed through holes.

LABORATORY STUDY OF A LILY

Each pupil is to be provided with a lily.

Draw the flower and label the parts as follows: (1) *perianth*, the large outer parts taken together; (2) *stamens*, the slender parts bearing the yellow, dust-like *pollen;* (3) *pistil*, the central part of the flower; (4) *peduncle*, the flower stalk.

How many divisions has the perianth? Are they all the same shape, size, and color? Have they all furrows or markings leading to the base of the flower? Are there drops of *nectar*, a sweet substance, at the base of the stamens?

How many stamens are there? Draw one and label (1) *filament*, the stalk-like part; (2) *anther*, the enlarged top which bears the pollen. If possible, examine the pollen grains with a microscope.

Draw the pistil and label (1) *stigma*, the enlarged upper end; (2) *style*, the slender portion below the stigma; (3) *ovary*, the enlarged base. How many lobes has the stigma? Is it sticky? Are there pollen grains upon it?

Cut across the ovary. How many chambers has it? Are there few or many ovules (small, white bodies) in each? Draw. Label the parts to which the ovules are attached, *placenta*.

Let a lily stand in water till it withers. What parts have dried up? What other changes have taken place? Cut across the ovary. Compare with your drawing and tell what differences you see. Draw the ovary as it now appears.

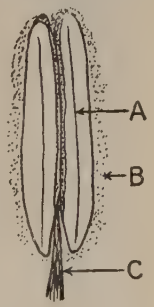


FIGURE 311. — STAMEN OF LILY. *A*, anther; *B*, pollen grains; *C*, filament.

358. Functions of the Parts of a Flower. — The *sepals* are adaptations for the protection of the inner organs while they are developing, and the *petals* are adaptations for the purpose of attracting insects to distribute pollen. Sometimes one set of these organs is lacking and sometimes the other. Very often, sepals are colored and serve the purpose of petals, another adaptation. The receptacle serves as the place of attachment for the other parts of the flower.

The *stamens* produce the pollen without which seed cannot be formed. Concerning the ways in which they open, the kind of pollen they bear, their adaptations for getting it to the pistil of another flower and (usually) for keeping it from its own, enough has been discovered to furnish text for a whole book, although many flowers have not yet been studied at all. Many of these facts can be observed by any

boy or girl with keen eyes. To be on the lookout for new facts will give zest to the study of botany.

In the ovary of the *pistil* are found the ovules which will become seeds under favorable conditions (see sections on Pollination and Fertilization). The stigma and the style are parts which help to fulfill these conditions. The position of the ovules in the ovary, the adaptations of the stigma for catching and holding pollen, the position of the stamens with reference to it, the adaptations of the pistil for the passage of the pollen tubes through it, — all these furnish the basis for a fascinating study which can be carried on by any one who has access to flowers, and who has time and patience.

When a flower has finished its work, namely to secure the fertilization of the egg-cell in its ovules, its showy parts, if it had any, wither, and the fruit begins to form. Usually it is only the ovary which enters into the fruit; but in some cases, the receptacle is included.

HOME WORK

Examine vacant lots, waste spots, and gardens for weeds. How many of them are composites? See page 505.

Study flowers in vacant lots, and record the results, using the following table as a guide.

	Corolla Regular	Corolla Irregular	Corolla Lacking	Stamens only in a Flower	Pistils only in a Flower	Flower Perfect
Geranium . . .	X					
Castor bean . . .						
Salvia		X				
Nasturtium . . .						X
Pansy		X				
etc.						

359. Types of Inflorescence. — This term is used for the act of flowering and for the arrangement of flowers on the

FIGURE 312. — SPIKE.

A raceme in which the flowers have very short pedicels or none, as plantain, Figure 317.

FIGURE 313. — STAMINATE FLOWERS OF POPLAR.

Catkins are a form of raceme.

stalk. Flowers that grow at the end of a separate stalk, like the common blue violet, tulip, daffodil, water lily, and hepatica, are *solitary flowers*. As a rule, they are larger

and more showy than those which are arranged in clusters. It is not necessary to learn the types of inflorescence, but for those who are interested the following brief discussion is given.

FIGURE 314. — COMPOUND UMBEL OF WILD PARSNIP.

This form of inflorescence is a distinguishing mark of a whole family of plants.

Raceme. — This is a stem which bears flowers on both sides or spirally, each flower having a bract or reduced leaf at its base. The flowers may all hang from one side of the stem as in lily-of-the-valley or currant.

Umbel. — All pedicels arise around a central point, the outer ones being longer.

Thyrse. — This is a compact panicle forming an oval or pyramidal cluster, as bunch of grapes, lilac, horse-chestnut blossoms.

Head. — This is a raceme in which the axis is very much flattened, or much rounded, as clover.

Corymb. — This is an inflorescence in which the lower pedicels are longer, forming a flat-topped cluster, as hawthorn.

In a raceme, spike, panicle, and head, the axis may go on growing and producing flowers during an indefinite period. This is known as *indeterminate inflorescence*. Indeterminate inflorescence has its oldest flowers on the lower part of the axis

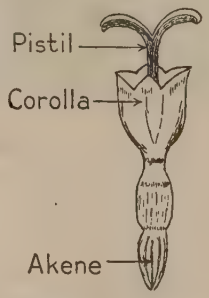


FIGURE 315. — DISC FLOWER OF DAISY.

(raceme, spike, head) or on the *outside* of the cluster (corymb). The order of blossoming is centripetal.

FIGURE 317. — SPIKE OF PLANTAIN, A COMMON WEED.

Composite Flowers. — This term is applied to flowers which are closely crowded or grouped into a head, on a common receptacle. Such is the dandelion or the daisy, each group being commonly called a flower. Two kinds of flowers are to be found in these heads, *tubular flowers*, that is, with the corolla a tube, and *strap-shaped* flowers in which the corolla is long and slender. Some composite flowers, like the dandelion, have only the strap-shaped, and others, like the thistle, only the tubular kind Still others, like the common daisy and the sunflower, have both kinds. In the daisy, the tubular flowers, found only in the middle, are called *disc flowers*. These make up the yellow part of the group. Outside of them are the white, strap-shaped kind, known as the *ray flowers*. In the sunflower the disc flowers are brown, and the ray flowers yellow.

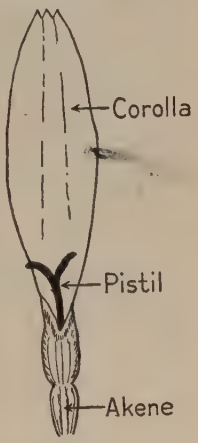


FIGURE 316. — RAY FLOWER OF DAISY.

360. Pollination. — When insects go to a plant to get nectar, they are helped by adaptations of the flower to become

covered with pollen as they leave the flower. Still other adaptations bring it about that when the insect enters a flower, some of the pollen from the flower last visited is left on the stigma of the one which it is entering.

This *pollination* is only the first step in the production of seed. Before we can understand the use of pollination, we must understand the structure of the pollen grain which is a cell.

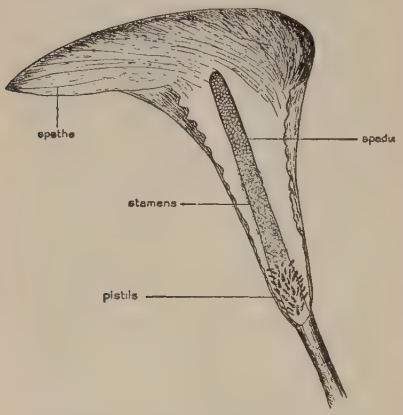


FIGURE 318. — FLOWER OF CALLA.

Both pistils and stamens grow on the spadix. This is inclosed by the white spathe, a modified leaf. Jack-in-the-Pulpit has spathe and spadix.

FIGURE 319. — FLOWER OF COLUMBINE.

Showing spurred petals. Only a long-tongued insect can reach the nectar. Note the bunch of stamens upon which the insect alights.

Pollen grains present the greatest variety in size, structure, and markings, but all have some features in common. They all have a double coat or covering, the outer side of which is thin in places. When a pollen grain is caught on a sticky stigma, it soon sprouts; that is, the inner coat pushes out through the thin places in the outer coat, producing a tube. This contains the protoplasm of the pollen grain, and two nuclei, one of which, the *sperm nucleus*, will join with that

found in the ovule, the *egg nucleus*, to start the new plant formed in the seed from the fertilized ovule.

The pollen tube and the style both show adaptations. The style is either tubular, affording a path for the pollen tube, or it is composed of cells very loosely packed, allowing the tube to pass through it readily. The adaptations of the tube are its ability to absorb food from the tissues through which it passes, and to find the opening of the ovule.

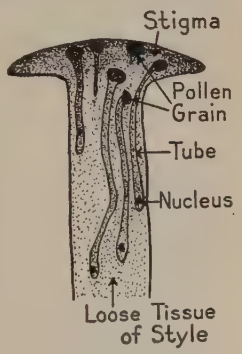


FIGURE 320. — POLLEN GRAINS SPROUTING AND GROWING THROUGH STYLE.

FIGURE 321. — POLLEN GRAIN SPROUTED.

The upper nuclei are male or generative nuclei.

Cross-Pollination. — Pollen is necessary for the formation of seeds, and in most cases it is the pollen of some other plant of the same kind that is used. When the pollen of one flower is transferred to the stigma of another of the same kind, the process is known as *cross-pollination*. On the other hand, when a stigma gets pollen from the stamens of its own flowers it is said to be *self-pollinated*.

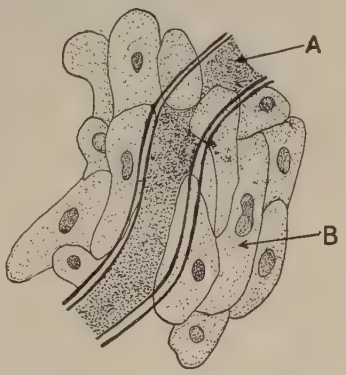


FIGURE 322. — PORTION OF POLLEN TUBE DISSOLVING ITS WAY THROUGH LOOSE TISSUE OF STYLE.

The distribution of pollen is accomplished by insects and by wind more than by other

agents. Pollen that is to be scattered by wind has two adaptations: (1) it is very abundant, for much of it is sure to be lost; (2) it is light, that it may be easily carried. The pollen of pines, which is so abundant as to cause the so-called "sulphur showers" in the spring, illustrates this, and the pollen of grasses, which is extremely light, illustrates the other fact. Plants that are wind-pollinated usually lack odor and color and floral envelopes (accessory parts), but they have adaptations in the stigmas, which are either plumy or feathery or broad and sticky, the better to catch and hold the pollen grains brought to them by the wind. Seeds formed as a result of cross-pollination produce a larger number of vigorous plants than those which grow from seeds in self-pollinated flowers.

FIGURE 323. — FLOWERS OF WILLOW. "Willow pussies" are the staminate flowers in their early stage.

Self-Pollination. — Some flowers, like the cleistogamous flowers of the violet, are arranged with a view to securing self-pollination. Most flowers, on the other hand, have adaptations to prevent it.

One of these devices is to produce pistillate flowers only on one tree and staminate flowers only on another tree or plant. The willow does this. A second adaptation is to

have the pistil mature first and the stamens last as the plantain does, or to have the stamens mature first and the pistils last as the dandelion does. A third is to have long stamens and a short pistil, or short stamens and a long pistil. When an insect visits such a flower, one part of its body is apt to come into contact with the stamens and another with the pistil. For example, in the primrose, an insect which gets pollen from short stamens on its body in one flower leaves it on the short stigma of another flower.

Artificial Pollination. — In artificial pollination, pollen from one flower is carefully transferred by hand to the stigma of another flower of the same kind. Usually this flower had its stamens removed before the pollen was ripe. It must be protected from the visits of insects after it has been pollinated artificially.

FIGURE 324. — STAMINATE FLOWERS OF CORN, THE "TASSEL."

Corn is a wind-pollinated plant.

Artificial pollination is practiced to develop new varieties of fruits (see page 11) and of cereals (see page 651). Luther Burbank has made use of this method in many of his experiments on fruits and flowers.

It was formerly thought that cross-pollination was necessary to produce vigorous plants. Its chief value seems, however, to be to produce variations.

361. Fertilization. — The union of the pollen nucleus with the nucleus of the egg cell is called fertilization. Without it, the ovule never develops into a seed. (Look in pea or

bean pods for unfertilized ovules ; in the seed-case of an apple ; on an ear of corn.)

Successful fertilization depends much on thorough pollination. For this reason farmers and gardeners should know the habits of the insects which pollinate flowers and the best way to plant certain crops to secure the results desired.

FIGURE 325. — PISTILLATE FLOWERS OF CORN.

Each grain had a long green style, the "silk." Corn husks are modified leaves.

How Fertilization Is Accomplished. — When pollen grains fall on a stigma they are held there by a sticky substance or by projections, and each soon puts forth a tube. These tubes make their way through the style. If the style has a channel, the tubes pass down the sides of that. If the style is filled with loose tissue, each tube makes a path for itself by dissolving and living upon the cells that are in its way.

The nuclei are always near the end of the tube, which may become very long compared to the size of the grain which produced it. (See Figure 321.) When it reaches the ovary it turns towards an ovule, which it enters, usually through the micropylar opening. When the tip of the tube containing the male nucleus touches the egg cell in the embryo sac, it bursts, and its nucleus unites with that of the egg cell, completing the act of fertilization.

As soon as the egg cell is fertilized it begins to divide, forming the new plant. At the same time other changes take place which result in the formation of a seed. (See page 506.)

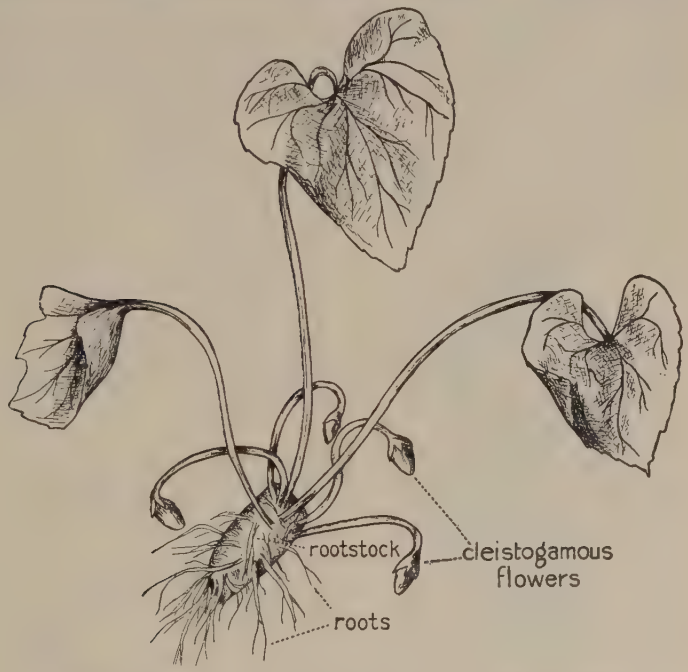


FIGURE 326. — VIOLET PLANT WITH CLEISTOGAMOUS FLOWERS.
These look like buds, as they grow below the surface and never open. Their one or two stamens pollinate the pistil thoroughly.

SUGGESTIONS FOR DEMONSTRATION BY TEACHER

Direct the observations of pupils in studying the flowers of a dandelion. Note old (mature) flowers on the outer part of the head, and young (immature) flowers in the inner part. Note the notches at the end of the long corolla. What does this indicate? Note the number of filaments, and the anthers united in a ring, opening on the inside. Call attention to the fact that the anthers mature before the pistil does. Show how the pistil, with its stigmatic surfaces pressed tightly together,

pushes up through the pollen which fills the tube, becoming covered on the outside. Show mature pistil with expanded stigma. If possible show dandelions with insects on them. What are the insects doing? What happens to the pollen?

Pollen Grains. — Place a few, preferably large ones, on a slide; cover with 5 per cent sugar solution; put under a bell jar and set in a warm place for half an hour. Then add a cover glass and examine for pollen

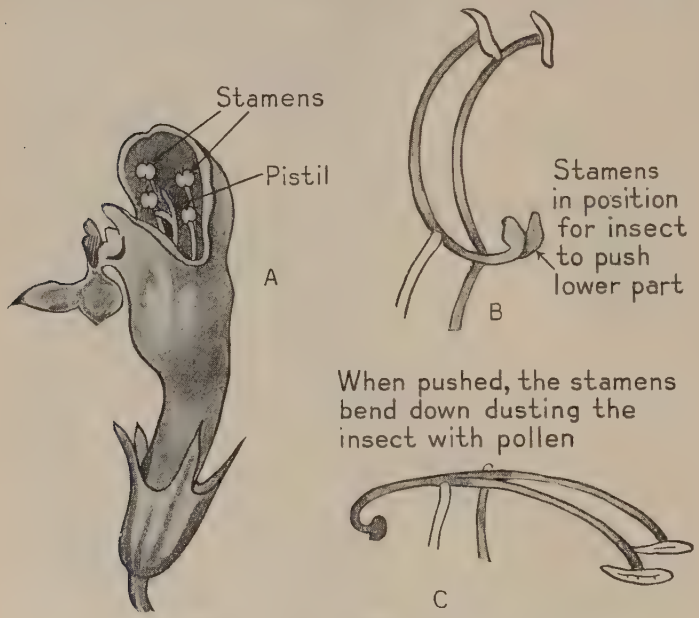


FIGURE 327. — FLOWER OF SALVIA.

A, whole flower. Note the platform where the insect alights.

tubes. Examinations may be repeated at intervals for a number of hours.

Carefully split the style of a large flower, like a lily, noting the passage in the middle for the pollen tubes. If the pistil has not a tubular center, what is the character of the tissue in the center?

362. Adaptations for Pollination. — The flower of the *nasturtium* offers a good example of adaptations. You will

notice that (1) it has a striking color in contrast with the foliage. This enables insects to see it readily. (2) It has an odor. This enables insects that are guided largely by the sense of smell to find it. (3) It has a long nectar spur on one side of the flower. This attracts the larger insects for the food they can get. (4) The lower petals have an inner fringe which retards the crawling insects that are trying to get the nectar. (5) The upper petals project over the other parts of the flower. This keeps the rain from running down the nectar spur and prevents the pollen from becoming wet. (6) The lower petals have stripes that lead to the opening of the nectar spur. This indicates the direction that insects should travel to find the opening quickly. (7) The anthers mature at different times. This insures a supply of pollen on different days so that some of the pollen is in condition to use, even if some has been spoiled by unfavorable weather. (8) The anthers and stigma mature at different times so that the pollen cannot get on its own stigma. There are at least eight ways in which the nasturtium flower is adapted to the visits of insects and to the protection of its pollen and nectar. There are many

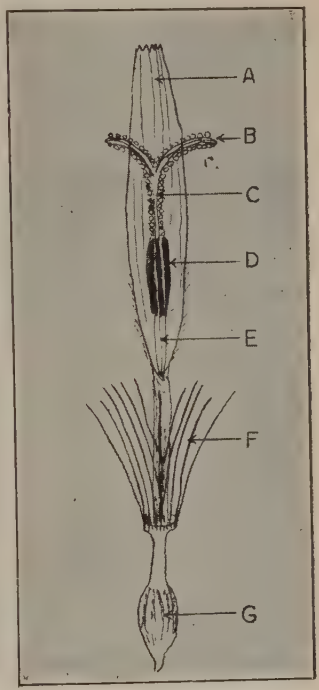


FIGURE 328. — FLOWER OF DANDELION.

A, strap-shaped corolla; *B*, stigmatic surface covered with pollen; *C*, style covered with pollen from its own anthers; *D*, ring of united anthers; *E*, filaments of united anthers; *F*, pappus; *G*, akene, young fruit.

other aspects of the study of flowers as interesting as the study of adaptation, some of which will be mentioned later.

Let us see what adaptations the *lily* has. (1) It is a large showy flower. Insects can see it easily. (2) It has a strong odor, enabling insects to locate it by smell. (3) It has a long pistil which protrudes beyond the other parts, affording a good place for insects to alight. (4) It has long stamens so arranged that when an insect alights on the pistil, it is sure to become dusted with the pollen from them. (5) Its pistil has a sticky enlarged end which is almost sure to catch pollen grains from the insect's body. (6) It has nectar glands around the bases of the stamens which yield food for the insects. (7) It has furrows in the petals leading to the nectar glands. This helps the insect to find the nectar. (8) The stamens bear the pollen on their outer surfaces, a safeguard against self-pollination. (See page 508.)

FIGURE 329. — LADY-SLIPPERS.

Dandelion flowers show many adaptations. The stamens are joined in a tube with the anthers opening on the inside. The anthers mature their pollen before the pistil of that flower is ready for pollen. The pistil, with its stigmatic surfaces pressed tightly together, pushes up through the mass of pollen filling the tube, becoming covered on the *outside*. Insects crawling over the head drag some of these pollen grains to pistils which are mature. When the pistil of

WILD MOCCASIN FLOWER.

This beautiful plant is in danger of becoming extinct through ruthless picking.

any one flower expands, its own pollen is not likely to get on it.

The closely crowded flowers, the arrangement of their parts, the bright color, the abundant pollen, and the certainty of cross-pollination are adaptations which make the dandelion one of the most successful of plants.

The composites as a whole show more adaptations than

FIGURE 330. — PINK LADY-SLIPPERS.

One of the disappearing orchids. In many places incessant picking has exterminated it. It is doomed to extermination unless the boys and girls start a crusade to save it from the older men and women who are old-fashioned in their way of appreciating wild flowers. Orchids are perennials, but they need their leaves to store up food for next year's blossoms and seeds. Naturally they fruit every year, and the older plants are surrounded by little groups of seedlings, which is nature's way of stocking the woods with these delightful flowers. Every one that is picked and brought in tends to make the woodland barren and so much less attractive. Spare the wild flowers!

other flowers, so we find among them those which are of most interest to the scientist and those which are of greatest annoyance to the farmer, namely, dandelion, paint-brush,

FIGURE 331. — A RARE ORCHID.

burdock, and thistles of all kinds. They are most successfully fought by not giving them opportunity to blossom and form fruit.

363. Conservation of Wild Flowering Plants. — It would be a poor course in biology that did not emphasize the pleas-

ure which knowing our wild flowers gives all lovers of nature. We are coming to feel that animals and plants which give us pleasure should be permitted to live. Game laws and animal preserves are helping to protect some of our rare animals that were being destroyed by man.

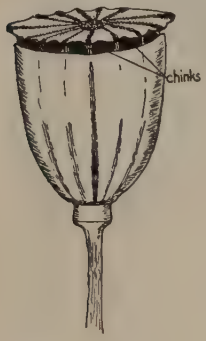


FIGURE 332. — DEHISCENT CAPSULE OF POPPY.

Note the openings through which the seeds sift.

For twenty years flower protection organizations have been urging that the rarer wild flowers should be protected by law. During the year of 1923 several states passed laws against the indiscriminate picking of wild flowers. You should do your part in helping to make this new legislation effective.

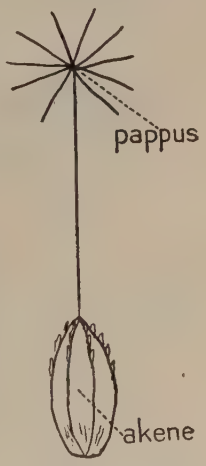


FIGURE 333. — DRY FRUIT OF DANDELION, THE AKENE.

Owing to the limited area of wild tracts, particularly near cities, wild flowers will soon disappear utterly unless the public is educated to enjoy them as they grow. The study of plants which you have just made tells you about their habits so that you may know how to deal with them. For instance, little harm is done by picking the flowers of *trillium*, because its thickened stem, deep in the ground, will put up another flower stalk the next year, if it has food enough stored to enable

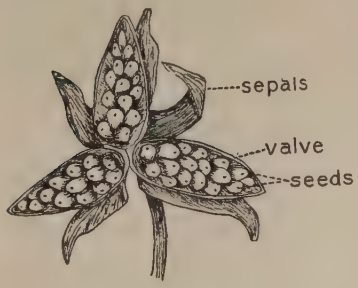


FIGURE 334. — EXPLOSIVE CAPSULE OF VIOLET.

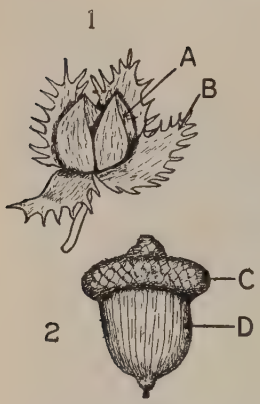


FIGURE 335. — DRY FRUITS.

1. Beechnut. The seed is inclosed in the pericarp (*A*), and the whole surrounded by the bur (*B*), which was formed from the involucre.

2. Acorn. *C*, cup formed from involucre; *D*, seed inclosed in pericarp.

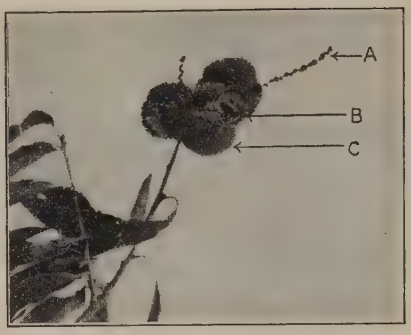


FIGURE 336. — CHESTNUT, A DRY FRUIT.

A, remains of staminate flowers; *B*, nuts; *C*, bur.

it to do so. In the case of *arbutus*, however, it is difficult to pick the blossoms without pulling loose from the soil the long trailing stem, which is then left to die. Picking the flowers of *dogwood* destroys the attractiveness of this shrub. The *orchid* is another species of wild flower that is rapidly disappearing because people are incessantly picking it. In many places it has been nearly exterminated.

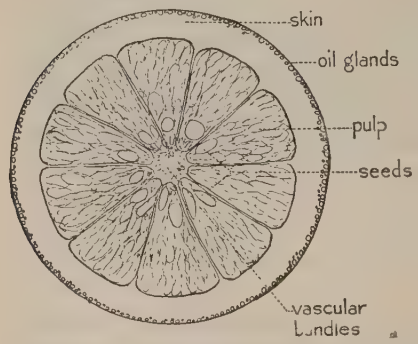


FIGURE 337. — CROSS SECTION OF ORANGE.

In your study of the flower, you have learned that the seeds are developed in the flower, and if you pick all the flowers no seeds can be formed. Lovers of wild flowers are coming more and more to enjoy leaving them where they

grow instead of picking them for decorating their homes, where they last for only a few hours at best.

Photographing wild flowers where they are found growing is a form of recreation that is becoming popular.

364. Types of Fruits. — The fruit of a plant is the final result of the work of the flower. In its simplest form it is the ripened ovary and its contents, including the seed or seeds. In some cases, however, it involves accessory parts of the flower as well, especially the receptacle. The wall of the ovary in a fruit is called the pericarp.

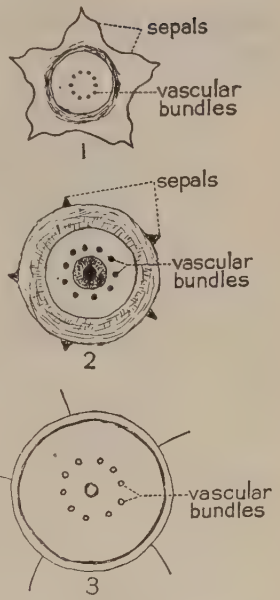


FIGURE 338.

1. The stem end attached to the orange.
2. Under side of stem end.
3. Pit in orange after removal of remains of stem.

Fruits are either *fleshy:* berry, drupe, (stone fruit), or *dry.* Dry fruits are of two kinds, (1) those that open (dehiscent), bean, poppy, and violet; and (2) those that do not (indehiscent), nuts, corn, samara of maple.

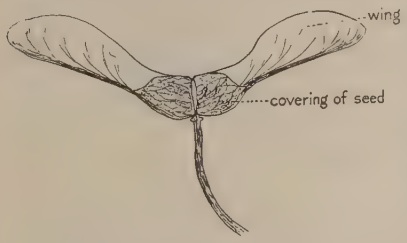


FIGURE 339. — SAMARA OF MAPLE.
A dry, indehiscent fruit.

A grain of corn or wheat is a typical indehiscent fruit. The pericarp, though very thin, is hard and flinty, furnishing effective protection to the inclosed embryo and food.

Function. — The fruit is of use to a plant in

two ways, (1) in protecting the seeds during their development, as in the bean, or during their period of dormancy, as in the nut, and (2) in helping to distribute the seeds after they are matured, as in the burdock.

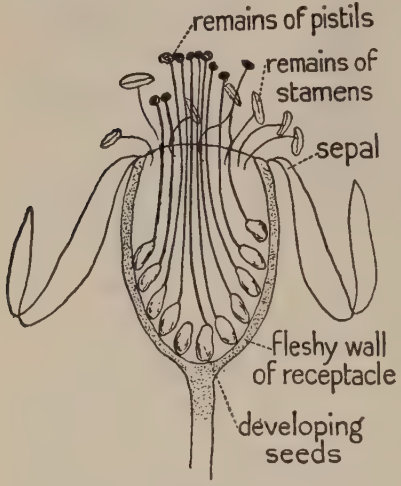


FIGURE 340. — DIAGRAM OF FRUIT OF ROSE.

The fruit of most plants is the part that is of greatest use to man, furnishing him most of the necessities in the way of food, and many of the luxuries.

LABORATORY STUDY

Study of an Orange. — Examine the stem end and note the remains of the calyx. How many sepals had the flower? Remove it. How many dots do you see? These represent the ends of the vascular bundles which supplied food to the growing fruit. Examine the opposite end for scar showing where the pistil was attached. Scrape the skin or pinch it, and note the oil which shows as a yellow, odorous liquid.

NOTE. Place a drop of this oil on linen paper. Note the spot it leaves. After a day examine the paper. Is the spot still visible? Oils that evaporate, leaving no spot, are called *volatile* or *essential* oils. Place peanut, Brazil nut, or castor bean on a linen paper. Heat till a clear spot shows. Lay aside and examine from time to time. Does the spot disappear? Oils that do not evaporate are known as *true oils*.

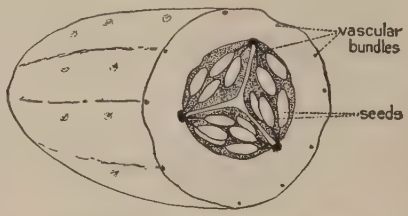


FIGURE 341. — CROSS SECTION OF CUCUMBER.

A fleshy fruit.

Make a cross section through the middle of the orange. How many distinct parts are there? Where are the seeds? Note the oil glands in the cut skin. Draw and label the parts named above.

Remove the skin from a whole orange and separate the parts. How many are there? Look for a strand of conductive tissue on each one. Where do they come from? Compare the number of sections with the number of vascular bundles on the stem end.

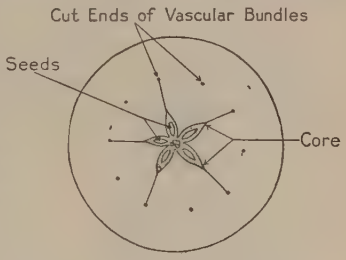


FIGURE 342. — CROSS SECTION OF APPLE.

Study of a Tomato. — Examine the whole fruit for traces of parts of the flower. On which end are they found? How many sepals were there in the flower? Remove the stem and count the number of vascular bundles. Make a cross section through the middle. How many divisions in the tomato? Where are the seeds? Note the mucilage with which each is surrounded. Can you see the vascular bundle which entered it? Note the very thin skin. Draw and label all. The tomato is a berry.

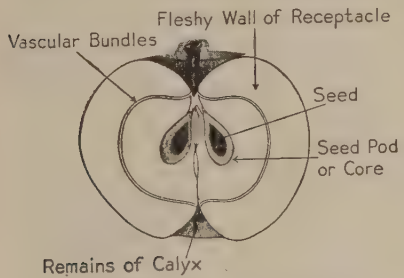


FIGURE 343. — VERTICAL SECTION OF APPLE, A POME.

NOTE. Canned, unpeeled tomatoes will serve. Compare grape, another *berry*, and peach, plum or cherry, *drupes*.

Other pomes are quince and pear. The thickened receptacle becomes consolidated with the pericarp. The papery endocarp is the core. The fruit of the rose, Figure 340, shows the relation of parts.

Study of an Apple. — Examine the whole apple. On the blossom end find the old sepals. How many? In the end of the stem look for vascular bundles. Draw and label. Make a cross section through the middle. Draw. Label the seeds in the papery pod (core). How many divisions has it? How many vascular bundles, as shown by dots near the core?

Make a vertical section. Label vascular bundles when seen, stem,

fleshy wall of receptacle, and remains of sepals. Are the remains of sepals on the same end in the apple as in the orange?

HOME WORK

Draw a pod of bean or pea showing valves, seeds, remains of sepals, and place where pistil was attached. Examine fruit of dandelion, milkweed, and other weeds as you find them. See how many kinds of fruits you can find. Make a list of fruits obtained.

FIGURE 344. — CLOTBUR OR COCKLEBUR.
This is both hooked and buoyant.

365. Adaptations of Fruits and Seeds for Dispersal. — Before any fruit has fulfilled its function, it must scatter the seeds it contains. This is necessary for three reasons, at least. (1) There would be too much competition if all were dropped near together; (2) there would be too slow progress, for the soil near the parent might be depleted, and the new plants could not grow as well there as in fresher soil; and (3) there would be too great a chance of extermination if all were dropped near together, for some one unfavorable condition might kill them all.

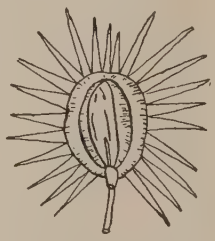


FIGURE 345. — FRUIT OF WILD CARROT.
This is distributed by wind and by animals.

In order to scatter seeds a plant makes use of wind, animals, and water as distributing agents, and of such mechanical devices as exploding pods. To be distributed by the wind, a seed or a fruit must be light. This is brought about in some plants by plumes, as in the case of the akene of the dandelion, thistle, and clematis, by the down

on a milkweed seed, and by the wings on the fruits of the maple and elm. (Review § 17.) Special devices for wind distribution are found in the Russian thistle and in tickle-grass, a common garden weed. In the former case the whole plant breaks off at the level of the ground, and is blown about by the wind, fruits and seeds being broken off and scattered as it rolls along the ground. This is one of the worst weeds of sections of the western states. In tickle-grass, only the panicle is broken off, but the result is the same.

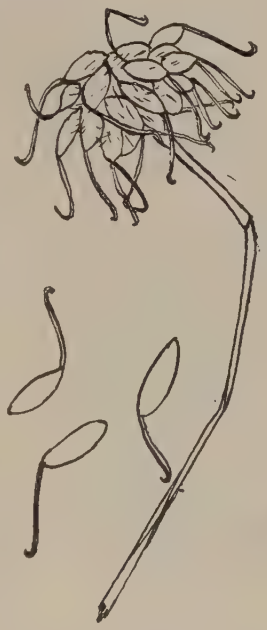


FIGURE 346. — FRUIT OF AVENS. "Beggar's tick."

To be carried by animals, the adaptations may be of two kinds — either they must have hooks to catch on or they must be edible. The burdock and beggar's tick represent the first kind of adaptation, and the fleshy fruits the second. In some cases only the fruit is eaten, as with peach, plum, etc., and the seeds dropped; and in other cases the seeds and all are eaten, but are not acted upon in the digestive tract, and so are dropped far from the spot where they grew, as with berries, apples, pears, etc. (Review § 147.)

FIGURE 347. — FRUIT OF HOUND'S TONGUE. A "Sticktight."

To be carried by water, the adaptations must be such as will insure buoyancy and the ability to withstand decay. Both are well illustrated by the coconut, and

the former by the cocklebur. To be distributed by being forcibly expelled, the fruits must have elastic tissue. The jewel-weed or touch-me-not illustrates this, as does witch-hazel, wild cucumber, and violet.

Besides the distribution of seeds by means of scattering the fruit or the seeds, plants have other means of propagating themselves which will be spoken of as they occur. The main dependence for keeping up the race, however, in most plants, especially the wild ones, is the distribution of its seeds. The fruit of a plant, so far as its relation to the plant that bore it is concerned, is simply a device for securing the distribution of the seeds it contains.

FIGURE 348. — FRUIT OF WHITE MUSTARD
A modified pod.

Dry fruits show many adaptations, most of which are based on some peculiarity of the pod. Take the bean for example. The pod is elastic. When it dries this causes it to split, then to curl up, throwing the seeds out by force. A pod which has elastic tissue is the wild cucumber which forces its seeds out violently. Still another is the witch-hazel. A pod which explodes violently is that of the jewel-weed, which requires only a touch to set it off, scattering the seeds far and near.

A capsule differs from a pod chiefly in having more than one chamber in immature stages. A capsule usually splits in several places, one for each chamber of the ovary, an adaptation for releasing all the seeds.

The adaptations of *fleshy fruits* are (1) a sour or bitter taste during development. This prevents their being eaten before the seeds are mature. (2) Edibility when ripe. This insures their being eaten by some animal, sometimes without the seeds, which are likely to be dropped some distance

from the plant which produced them; or seeds and all, in which case the undigested seeds are passed off with other wastes, often very far from the parent plant.

366. Economic Value of Flowers and Fruits. — Many plants are cultivated for the pleasure their flowers give us. Cauliflower, the buds of which are used as food, is the most familiar example of the use of flowers for this purpose.

A few have been used for medicine, though not so many now as formerly. Among them may be mentioned dandelion, the elder, the mullein, and camomile.

Saffron, a yellow coloring matter, is obtained from the stigmas of the saffron crocus.

SUGGESTIONS FOR HOME WORK

As soon as flowers appear observe them closely and note which have many insect visitors and which have few or none. Fill out a report as suggested below and add any points which interest you besides those mentioned.

	Color Conspicuous	Color Not Conspicuous	Odor Strong	Odor Not Strong	Nectar Abundant	Nectar Not Abundant	Insects Many	Insects Few	Etc.
Sweet Pea . .									
Dandelion . .									
Hepatica . .									
Buttercup . .									

Examine florists' and gardeners' catalogues, and note the plants the flowers of which are used as food and for ornament. Read about the use of hops and the process of raising and harvesting them.

The Uses of Fruits to Man. — In speaking of the uses of fruits to man, it must be remembered that all the grains

are fruits and that many so-called vegetables are fruits, as the tomato, and squash, and the cucumber.

The most valuable source of food in the world is found in the cereals: wheat, oats, rye, rice, barley, and others. Nearly half of the population of the globe depends on rice for its principal food. Rice is the only one of the cereals that is commonly eaten entire. The others are usually ground and made into bread. The importance of bread as an article of food is shown by the term, "the staff of life," which is often applied to it. In the famine-stricken regions during the late war, the hungry cried for bread more than for any other article of food. A diet consisting of bread and nuts furnishes all the elements of food.

FIGURE 349. — CATTAILS.

The slender tip was once covered with staminate flowers. The brown "cat-tail" is made up of fruits, adapted to distribution by the wind.

Not only are the cereals the most important article of food, but they are the basis of a great part of the world's work. The raising of cereals, their preparation for food, and their distribution give employment to a greater number of persons than any other industry. Much more attention is now given to agricultural education than formerly, because agriculture as an industry is now better appreciated. Besides supplying man with food directly, many cereals are used to feed the animals which he raises for the meat, milk, butter, cheese, and eggs which they produce. Man's beasts of burden live largely upon cereals too.

The articles of food commonly known as fruits, — apples, oranges, berries, bananas, and others, — are valuable, their chief use being to supply variety to the diet. The fruits obtained from the vegetable garden, — tomatoes, cucumbers, squashes, egg-plant, melons, and others, — furnish some foodstuffs.

Uses of the Terms Fruit, Seeds, etc. — It will be evident by this time that the words fruit, seeds, and nuts have a different meaning in botany from their ordinary use. The term "seed corn" and "seed wheat" used by farmers is correct in the sense that it indicates the corn or the wheat which is planted or sowed to produce a new crop. The so-called Brazil nut of commerce is in reality a seed. The fig is a "fruit" composed of a thickened and hollow receptacle, the end of a branch, on the inside of which are produced the real fruits commonly known as seeds.

HOME WORK

Cereals. — What articles of food on your breakfast table were cereals? Where were they raised? How were they brought to your home? What kinds of food were furnished by each? Look up the population of China, India, and Japan for the year 1915 or later. Most of these people live chiefly on rice. How does that compare with the number in the northern countries of Europe and the United States who live largely on the other cereals?

Fruits. — The raising of fruit is one of the large industries of the United States. The Great Lakes region, especially the shores of Lakes Erie and Ontario, are famous for grapes, apples, peaches, plums, and cherries. California produces large crops of oranges, grape fruit, lemons, prunes, figs, and grapes. Florida has long been noted for its oranges and grape fruit. Oregon, Washington, and Virginia produce large crops of apples. Each kind of fruit requires a special kind of soil and certain conditions of climate, and each has certain kinds of enemies. Look up the enemies of the apple tree. How is each combated? How does the life history of the codling moth differ in eastern states and the western states (Oregon and New York)? How is danger from frost avoided in Florida and California? How is moisture supplied in Oregon and Washington?

What kinds of birds are especially helpful in orchards? Why? What insect is helpful in the orange groves of California? Learn the history of it in this country.

What are the advantages of dynamiting the soil in setting out trees? How was the loganberry produced? How does grape juice differ from wine? Why is it necessary to prune vines and trees? Look up the history of grape fruit. How do navel oranges differ from others? Look up the history of navel oranges.

OUTLINE

- Structure of flowers
  - Sepals
    - Calyx
  - Petals
    - Corolla
  - Stamen
    - Filament
    - Anther
  - Pistil
    - Stigma
    - Style
    - Ovary
      - Ovules
      - Placenta
- Functions
  - Sepals
    - Protection
  - Petals
    - Attraction
  - Stamens
    - Pollen
  - Pistil
    - Ovary
      - Fertilization
- Inflorescence
  - Raceme
    - Compound
    - Head
  - Thyrse
  - Corymb
  - Composite flowers
    - Tubular
    - Strap-shaped
    - Disc
    - Ray
- Pollination
  - Sperm nucleus
  - Egg nucleus
  - Cross-pollination
  - Self-pollination
  - Artificial pollination
- Fertilization
  - Pollen
    - Tube
    - Style
    - Nuclei
  - Stigma
    - Ovary
      - Ovule
  - Adaptations
    - Color
    - Odor
    - Nectar
    - Protection
      - From insects
      - From rain
- Conservation
  - Arbutus
  - Dogwood
  - Orchids

Types of fruits
- Fleshy
- Dry
  - Dehiscent
    - Bean
    - Poppy
  - Indehiscent
    - Nuts
    - Corn
- Function
  - Protection
  - Distribution

Adaptations for dispersal
- By wind
  - Thistle
- By animals
  - Hooks
    - Burdock
  - Edibility
    - Peach
- By water
  - Coconut

Economic value
- Food
- Pleasure
- Medicine
- Coloring

SUMMARY

Flowers are the organs of the plant which provide for the production of seed and the continuance of the race. The pistils and the stamens are the essential parts of the flower. Colors, odors, and nectar are devices for attracting insects which bring about cross-pollination. Wind-pollinated flowers are usually inconspicuous, and they have an abundance of light pollen. The pollen grain is a cell which contains the sperm nucleus. This is carried to the egg cell in the ovule by a tube. The union of the two nuclei of these cells is fertilization. The fertilized egg cell develops into an embryo plant and the ovule develops into a seed which protects the embryo and contains food for its early life.

The fruit contains the seeds. It develops from the ovary of the flower. Its function is to secure the dispersal of the seeds. Some fruits are dry and some fleshy. Some of the dry fruits split open and some do not. Fruits are distributed by animals, by wind, and by water, and each kind has special adaptations to accomplish its end. Dispersal is necessary to give the new plants a better chance to grow. Fruits are of the greatest use to man as food. In many cases the quantity and the quality of the fruit man uses have been improved.

QUESTIONS

What is the function of flowers? What are the essential organs of a flower? What devices have flowers for attracting insects? What for wind pollination? What is the pollen grain? The ovule? What is fertilization? In what does it result? What is a fruit? What pur-

pose does it serve? How? What kinds of fruit are there? Describe a grape; a peach; a raspberry. What use is the fruit to man? How are fruits distributed? Why is dispersal necessary?

REFERENCES

Bessey, College Botany, page 285; pages 302–313; 321–324.
Snyder, General Science, pages 200, 201.
Bergen, Foundations of Botany, pages 186–216.
Conn, Biology, page 118.
Bergen and Caldwell, Practical Botany, pages 104–135.
Gibson, Sharp Eyes, page 115.
Coulter, Plant Life and Plant Uses, page 58; pages 258–321.

CHAPTER XXXI

SEEDS AND GERMINATION

Read my little fable
He that runs may read
Most can raise the flowers now
For all have got the seed.

— TENNYSON

367. The Bean from Ovule to Seed. — At the time of fertilization, an ovule of the bean consists of a mass of tissue (*nucellus*) in which is embedded the *embryo sac*. The embryo sac contains an egg cell which, if fertilized by a nucleus from the pollen tube, will become a young bean plant (embryo). The ovule is covered by two coats (*integuments*) which do not quite meet at one end, leaving an opening, the *micropyle* (mī′krō-pīl: Greek, *micro*, small; *pyle*, gate), a small door through which the pollen tube usually enters. It is attached to the wall of the ovary by a stalk through which it gets its nourishment.

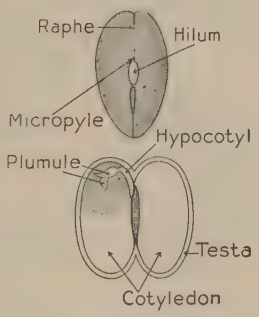


FIGURE 350. — BEAN SEED, SHOWING PARTS.

In developing into a seed several changes occur. (1) The coverings (integuments) become firm and hard, the outer forming the *testa*. (2) The egg cell divides many times, forming the *embryo*. (3) The embryo sac is replaced by two *cotyledons* which contain food for the embryo. (4) The micropyle becomes smaller and almost closes. (5) The stalk drops off,

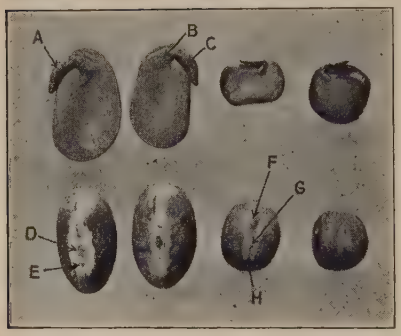


FIGURE 351. — SEEDS OF BEAN AND PEA.

Upper, split, showing embryo. (Only the part showing the embryo was saved.) Lower, whole, showing markings. *A*, embryo; B, plumule; *C*, root; *D*, hilum; *E*, micropyle; *F*, embryo; *G*, hilum; *H*, micropyle.

leaving a scar on the bean seed, the *hilum* (hī'lŭm: Latin, *hilum*, a little body).

368. Adaptations of the Seed. — The bean seed is the plant's way of providing for a new bean plant. It is adapted to fulfill that purpose in the following ways. (1) A ripe seed contains a young plant well started. (2) It can resume growth soon after being formed, or it can remain dormant for years. This might prevent total loss of seed. (3) It is surrounded by a hard testa which prevents the embryo from drying out during a long resting period. This enables it to remain *viable* (Latin, *vita*, life) for many years. (4) It can absorb water slowly through the micropyle when covered with moist earth. This softens the testa and causes the cotyledons to swell, helping to release the embryo. (5) The cotyledons contain food for the young plant till it can make its own. This insures rapid growth in the early stages, an advantage in competition with other seedlings.

FIGURE 353. — PLUMULE READY TO BREAK OUT.

Root free and growing downward.

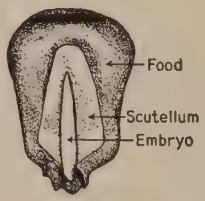


FIGURE 352. — UNSPROUTED GRAIN OF CORN.

369. Growth of the Bean Embryo. — When the embryo resumes growth after a resting period, the root breaks out of the testa first. This is an adaptation, for it at once begins to absorb water needed for further growth and soon becomes firmly embedded in the soil. This primary root is followed later by secondary roots.

The second adaptation is the curving of the hypocotyl (hy-pō-kŏt″l: Greek, *hypo*, beneath; *kotyle*, cavity). This

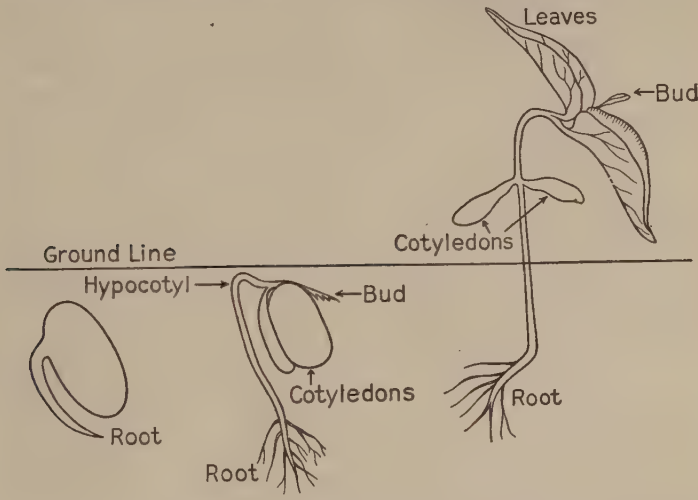


FIGURE 354. — GROWTH OF BEAN PLANT.

Left, root free; center, root branched, hypocotyl developed and showing the arch; cotyledons spreading, plumule showing; right, young bean plant. Note the shriveled cotyledons and the first true leaves.

forms a loop on top of which is a hard portion, the *peg*. The hypocotyl grows rapidly, causing the arch of the loop to turn from side to side, pushing the particles of soil apart and working its way to the surface. Then the cotyledons are pulled up as the arch straightens. Finally, further growth of the hypocotyl causes the cotyledons to spread apart, exposing the *plumule* (plūm′ūl: Latin, *plumula*,

feather) to the air and light. At the same time the cotyledons begin to turn green, thus serving as leaves till the leaves of the plumule have developed. So the plumule is protected and given a chance to grow under good conditions. As soon as the food in the cotyledons is absorbed by the young plant, they shrivel and drop off, while the leaf-stem and leaves continue to grow. The young bean plant is known as a seedling while it is dependent on the store of food in the seed.

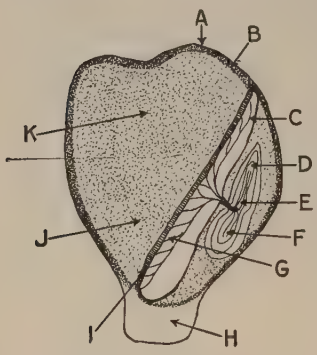


FIGURE 355. — DIAGRAM OF GRAIN OF CORN.

A, hard outer covering; *B*, protein layer; *C*, scutellum; *D*, plumule of embryo; *E*, hypocotyl; *F*, root; *G*, conducting vessels of scutellum; *H*, place of attachment; *I*, digestive cells of scutellum; *J*, *K*, starch (endosperm).

In the course of a few weeks a bean plant is large enough to produce blossoms which develop into pods containing seeds, thus completing the life *cycle*. The use of the seeds to the plant is simply to provide for other plants of the same kind, and to insure a supply of food for the early life of each. Man, however, has learned to take advantage of this habit of plants, to secure food for himself and his animals. He has also found ways of enabling the plant under cultivation to store up more food than it could do in the natural state.

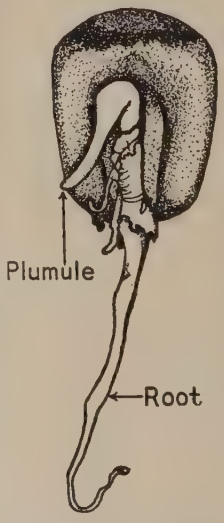


FIGURE 356. — PLUMULE FREE, BUT BENT BY ACCIDENT.

370. Corn "Seed." — A grain or kernel of corn, commonly called a seed, is like a bean (1) in containing a young plant, the

corn embryo; (2) in containing food for the use of the embryo when it first begins to grow; and (3) in having marks upon it. On one side of the kernel is a depression beneath which the embryo lies. Above the depression on each kernel is a slight prominence, the scar which marks the place where one thread of the so-called silks was attached. This is more prominent in pop corn. At the base is a stalk by which the kernel is attached to the cob during its development (Figure 355). Corn differs from the bean in the position of its embryo, which is at one side of the food supply. The latter is called the *endosperm* (ĕn′dō-spērm: Greek, *endo*, within; *sperma*, a seed). Another difference between the two is that the corn has a single modified cotyledon called the *scutellum* (skū-tĕl′lum: Latin, diminutive of *scutum*, a shield), the use of which is to absorb and digest the food and carry it to the embryo (Figure 355). The cotyledon of the corn never appears above ground. The corn embryo has its leaves rolled into a tight, pointed bud, an adaptation which enables it easily to pierce the earth above. The root is at the lower part of a short hypocotyl.

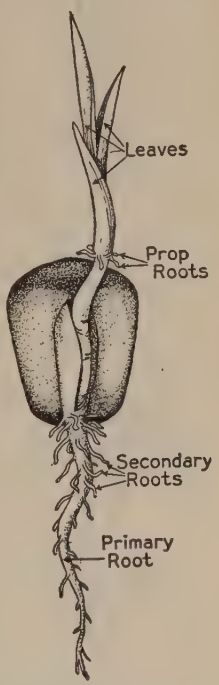


FIGURE 357. — PLUMULE UNFOLDED. Root system developing. Compare with Figure 358.

As the corn has but one cotyledon, it belongs to the class of plants known as monocotyledons (mŏn-ō-kŏt-y-lē′dŏn: Greek, *mono*, one; *kotyledon*, socket). The bean, having two cotyledons, belongs to the class dicotyledons (dī-kŏt-y-lē′dŏn: Greek, *di*, two; *kotyledon*, socket). Review characteristics of these classes, page 466.

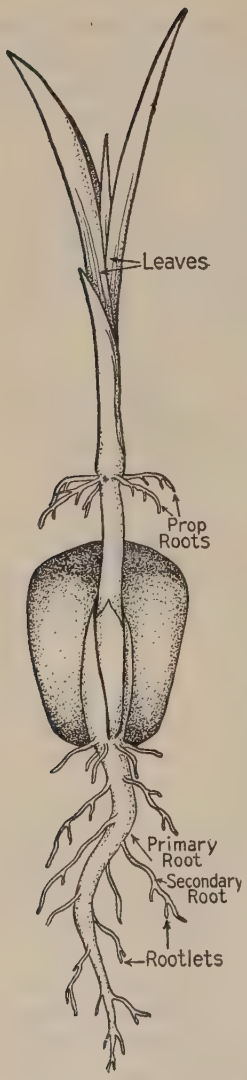


FIGURE 358. — ADVANCED CORN SEEDLING.

LABORATORY STUDY OF BEAN

Draw a bean in an upright position, holding the side towards you that has the hilum (a mark) on it. Label *hilum.* Near one end of the hilum is a small dot, the *micropyle.* Around the outside of bean, lengthwise, is a band or ridge, the *raphe,* ending at the hilum. Label micropyle and raphe. Split a soaked bean along the back. Draw the two parts. Label them *cotyledons.* On one of them is the *embryo* or young plant. Draw and label: (1) the pair of small, white leaves, the *plumule* or seed bud of the new plant; (2) the *hypocotyl,* below the plumule, from which stem and roots will grow; (3) *testa,* the hard covering.

NOTE. — Beans for class work should be soaked overnight at room temperature or for two hours in warm water.

LABORATORY STUDY OF CORN

Draw a grain of corn, broad end up, with the side showing the depression towards you. Label (1) *silk scar* on one side of top; (2) *scutellum* (under depression); (3) *stalk* by which it was attached to the cob (*hilum?*).

Cut lengthwise a kernel that has been soaked for half a day. Label (1) *embryo,* young plant; (2) *scutellum* (cotyledon) lying under embryo; (3) *endosperm,* store of food on which scutellum rests; (4) hard outer covering. Cut a kernel crosswise. Draw it, and label the parts as above.

Remove the embryo. Draw. Label plumule and root. Remove the scutellum. Draw.

371. Kinds of Foodstuffs Found in Seeds. — In the bean seed, two kinds of foodstuffs are stored, namely carbohydrates and proteins. Carbohydrate

(see page 39) is the name of the foodstuff which includes the starches and the sugars. Protein (see page 28) is the name given to the foodstuff found in such foods as lean meat, cheese, and the white of egg. Beans contain more protein than any other seeds.

Corn contains starch, sugar, and oil. Flaxseed and castor beans contain much oil.

LABORATORY WORK

Foodstuffs in the Bean. — The presence of different kinds of foodstuffs may be shown by applying the following (chemical) tests. Boil beans until they are soft and then place a small portion of them in a test tube. Add water and heat. Put in a drop of iodine. If starch is present, the mixture will turn blue in color. Add strong nitric acid to a second portion in a clean test tube, boil and cool. If protein is present, the mixture will be a clear yellow color which will become orange if ammonia is added. To a third portion add Fehling's solution[1] as a test for sugar. If the latter is present, the mixture will become dull orange when heated. Test uncooked seed for oil (1) by heating it over a lamp on a sheet of linen paper; (2) by soaking it overnight in ether. (This must not be near a flame at any time.) If oil is present, it will show on the paper as a clear spot, and in the second test the oil will appear on the surface of the ether in the test tube.

To Show that Seeds Contain Water. — Weigh some squash seeds very carefully after they have been peeled. Place them in a thin dish over a hot radiator for a few hours, then weigh again. Repeat the experiment, using other fleshy seeds. What do you learn from this experiment about the use of the testa to a seed?

To Show that Seeds Contain Mineral Matter. — Burn seeds to ashes in a crucible over a hot flame. What became of the carbon? What became of the water? What else was in the seed? Account for changes of form. What life process of the embryo uses carbon in the same way?

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[1] 1. Copper sulphate . . . . . 34.5 grams
Water . . . . . 500 cc.
Set aside until completely dissolved. This is solution number 1.
2. Rochelle salts . . . . . 173 grams
Caustic soda . . . . . 50 grams
Water . . . . . 500 cc.
Do not mix until ready to use, then take equal parts of each.

372. Where Foodstuffs Are Stored in Seeds. — In the bean, we have seen that both carbohydrates and proteins were stored in the cotyledons, evenly distributed, so far as we can discover. In the endosperm of a corn grain, the carbohydrates are under the scutellum, and the proteins in a distinct layer outside of the carbohydrates, covered by the flinty outside coat of the grain (see Figure 355).

373. Digestion of the Food in the Seed. — It may appear strange that the growing bean plant lives upon the food stored in the cotyledons, and yet such is the case. But this food must undergo a real digestion before the bean embryo can use it. We do not know just how this digestion takes place in the bean, but in the corn, as we have learned, there is a special structure, the scutellum, which helps to digest the food in the endosperm. Digested food is absorbed by the cells by osmosis, and passed into the phloem vessels, whence it is distributed to all parts of the plant through the vascular bundles. When scientists learn more about the digestive processes of plants they will probably find that they are similar to the same processes in animals.

LABORATORY STUDIES IN GERMINATION

To Teachers. — It is possible to make this one of the most valuable parts of biology to the pupils. Instead of making demonstrations it is suggested that the pupils be provided with material or asked to get it and work out the answers to the questions themselves, making their reports for each experiment under headings: Object, Apparatus, Procedure, Observations, Conclusions. They should be encouraged to think out new experiments when results do not agree, and they should be taught to make checks on their work.

The teacher should, however, perform the experiments at the same time, in order that time may not be lost. Each experiment should be preceded by a review of the knowledge the pupils already have about the topic.

Beans and corn for class work should be soaked overnight at room temperature, or for two hours in warm water.

Beans should be first soaked for several hours, then planted about a week before the lesson on seedlings.

To Show the Necessity of Stored Food. —

1. Remove the embryos from several seeds. Place them in soil under favorable conditions for growing.

2. Plant others under the same conditions except that the embryo is still inclosed by the cotyledons. Which grow? Why?

3. Remove most of the endosperm from a few kernels of corn. Plant these and compare the seedlings from time to time with those from whole kernels planted at the same time in the same dish.

4. Remove most of the cotyledons of a bean embryo. Place it in the earth or damp sawdust beside one which has whole cotyledons. Make sketches at each laboratory period to show the difference. What does this experiment show? Repeat the experiment with other seeds.

To Show that Germinating Corn Seeds Digest Starch. — Remove the scutellum from each of several grains of corn when softened by soaking. Remove some of the white part of the grain. Apply the test for starch and decide whether the white part of a corn grain contains much starch. Now place a thin layer of moist corn starch in a watch glass and upon it lay several scutella. Cover with a bell jar and set in a warm place overnight, taking care that it does not dry out. Then test with Fehling's solution. What change has taken place? What is the name of the process which changes starch to sugar? How is the sugar distributed? Invent an experiment to show the same change without removing the scutellum from the grain. (Hint, use wheat or oats, soaked and mashed.)

To Show the Necessity for Air. —

1. Boil a few ounces of water to drive out the air. Cool it. Place some seeds in it and pour paraffine or heavy oil over the top to shut out air. Set aside and examine from time to time. Use as many kinds of seeds as possible, including sunflower and unhulled rice.[1]

2. Do the same kinds of seeds sprout in water not boiled and sealed?

3. Plant some seeds in soil which is several inches deep and pack the earth firmly over and around them.

4. Plant others of the same kind, and pack the soil lightly. Which germinate better? Why?

To Show Production of Carbon Dioxide. — Germinate a handful of soaked peas, beans, corn, or oats in a wide-mouthed bottle. Fit the

[1] Rice is one of the very few plants that do not need air for germination. This is not saying that they do not respire, or that they do not need oxygen, however. An interesting adaptation of rice grains is that they have the ability to break water up into oxygen and hydrogen, use the oxygen so obtained, and set the hydrogen free. Other seeds, and animals that live in the water get their oxygen from air which is mixed with the water.

bottle with a rubber stopper with one hole in it. Bend into U-shape a glass tube of suitable size to fit the hole, making one arm longer than the other. Insert the short arm just through the stopper and let the longer one dip into a beaker containing lime water. Set aside overnight. What is the appearance of the lime water? What gas causes this appearance? Where does it come from? Do dry seeds give off carbon dioxide?

To Show that Germinating Seeds Use Energy. — Fill a small unglazed plant jar with bean or pea seeds which have begun to germinate. Fit a cover tightly into the top of the jar and wire it securely. Set the jar where growing conditions are favorable and observe what happens after a few hours. How do you account for this?

What causes thistles and burdocks to come up through old asphalt pavement? What causes the roots of trees to make flagstones irregular in height? Will a growing plant lift a weight? Look for potatoes that have been pierced by the underground stems of quack grass.

To Show the Necessity for Moisture. —

1. Place a few dry beans in dry sand in a warm room.
2. Place others in water near them.
3. Place others in moist earth near the other two. When any of the seeds sprout, decide which of the conditions are best for germination and why the others were unfavorable.

To Show the Necessity for Warmth. —

1. Plant two sets of seeds in moist earth. Set one dish in a warm room, seeing that it does not become too dry, and put the other in a refrigerator. Which germinate first? Why?

To Show that Soil is Necessary for the Normal Development of a Plant. — Germinate seeds of pea, bean, squash, and grains of corn in damp sawdust, in soil, and on damp blotting paper. Keep them under the same conditions of light, warmth, and moisture. Which germinate first? Which grow most rapidly? Which stand erect, and which droop first? Second?

Remove the roots of a plant grown in sawdust, and one grown in soil, being careful not to break off the rootlets. Compare with a plant grown on blotting paper. What differences do you notice? What use to the plant is the soil? Which will grow longest? What does the plant in the soil get that is lacking in the sawdust and the blotting paper?

To Show that Light is Necessary for the Normal Development of a Plant. — Germinate seeds of corn, bean, and pea in the dark and let them all remain there for five days after they appear above the soil. Compare them with others of the same kind planted at the same time

and kept under the same conditions except as to light, noting (1) differences in color, (2) in height, (3) in roots. How do you account for lack of chlorophyll? What other young, growing parts of plants lack green coloring matter? (See page 461.) Under what conditions were they grown as to light? What effect has light on seedlings removed from a dark chamber where they have been grown? How long does it take for the effects to show plainly? What changes of color do you notice in the plumules of young plants in the spring? In the buds of trees? In young leaves?

Turn a pail, box, or other covering that will exclude the light, over a patch of sod or a group of seedlings in some waste place. Note how many days it takes for them to lose their green color; how many days for them to regain normal color after being blanched.

To Show the Response of Stems to Light. — Place seedlings in jars before a window. What direction do they take? Turn some around. What happens after a few hours? Try the same experiment with an older plant. Which turns more quickly? Describe these experiments and invent others to show the same thing.

To Show the Response of Roots to Gravity. — Plant a seedling in damp sawdust with its plumule up and its roots down. Plant others beside it in other positions. After a day or two examine them all. What direction does the root always tend to take? The plumule?

To Show the Response of Roots to Moisture. — Plant seedlings in two separate boxes of moist sawdust. Keep the sawdust in one box moist, but allow that in the other to dry out. After several days, pull up the seedlings and examine the roots. What is your conclusion?

To Study Seedlings in General. — Place a box of soil in a warm room and keep it moist. Observe how many kinds of seedlings grow and how each gets out of the testa. How many kinds of seedlings do you find growing in your yard or garden?

Examine seedlings you can find in garden or field and classify them as monocotyledons or dicotyledons.

374. Economic Importance of Seeds and Seed Products. — In thinking of the seeds used as food, we must limit the term to its botanical meaning. Many articles of food, such as the cereal grains, are commonly thought of as seeds. Their use as food has already been discussed. (See § 366.) The real seeds that are of greatest use to man as food are those of the pulse family, especially beans and peas, which alone are the source of most of the protein that is obtained

from plants. The soy bean introduced from Asia is very valuable. Mature peas and beans contain more food matter than do "green peas" and "string beans," the latter being valuable more for the bulk they furnish than for their food content.

Besides their use as food, seeds can be used as medicine, castor oil and mustard being common remedies that are obtained from seeds. Castor oil is also used as a lubricant in airplanes on account of its not being affected by the cold of high altitudes. Two valuable products are obtained from cotton seeds: one the oil which is used in preparing foods in place of lard and butter, animal fats; the other, thread and cloth which are made from the fibers covering the outside of the seeds. The fibers are removed by a process called *ginning*, then the seeds are pressed to remove the oil. The refuse forms a valuable food for cattle, especially when mixed with other foods. The length of the fibers varies on different species of cotton, and the uses which are made of the fibers depend on their length.

Linseed oil is obtained from the seeds of the flax. It is used in making paint and other substances. After the oil is pressed out, a substance known as linseed cake is left. This is used as food for cattle.

OUTLINE

- Development of bean seed
  - Embryo sac
    - Fertilization
      - Pollen
    - Ovule
      - Micropyle
  - Testa
  - Embryo
  - Cotyledons
  - Hilum
- Adaptations of seed
  - Resumption of growth
    - Hard tests
      - Viability
    - Water absorption
    - Food storage
      - Cotyledons
- Growth of bean embryo
  - Roots
    - Primary
    - Secondary
  - Hypocotyl
    - Peg
    - Plumule

Growth of Corn
  Embryo
    Endosperm
  Cotyledon
    Scutellum
Foods in Seed
  Carbohydrates
    Starch
    Sugar
  Proteins
  Fats
    Oil
Digestion
  In scutellum
  Osmosis
Economic importance of seeds
  Foods
  Medicines
  Lubricants

SUMMARY

The seed is the plant's provision for a new generation. It contains the new plant and food for its early growth. Before a seed can grow, it must have the right conditions, warmth, moisture, and food. Before the embryo can use the food stored up in the seeds, it must digest it and distribute it. In getting free from the testa and in forcing its way through the soil, a new plant uses energy. Respiration releases the energy obtained from the food by oxidizing the carbon in the protoplasm of the young plant. The hypocotyl is the part of the embryo and young plant that helps it get out of the ground into the light. Although seeds will germinate without either soil or light, both are necessary for the healthy growth and development of a land plant.

QUESTIONS

What is the function of a seed? What are the parts of a seed? What are the conditions necessary for germination? For growth? What is a seedling? What kinds of foodstuffs are stored in seeds? Why does a young plant (embryo) need energy? What is the function of digestion to the embryo? Of circulation? Of respiration? What use does man make of the seeds of plants?

CHAPTER XXXII

FORESTS AND FOREST PRODUCTS

The groves were God's first temples.
—BRYANT

375. The Importance of Forests. — Forests are important directly for the lumber, fuel, and other products obtained from them, and indirectly in several ways less likely to be thought of. For instance, forests prevent floods and freshets. They do this in two ways, (1) by holding back the melting snow in the spring, thus making it possible for streams to carry off the water without overflowing their banks; and (2) by forming a soil which contains a large amount of organic matter called *humus* which has the property of absorbing water much as a sponge does, and letting it seep out gradually, thus maintaining a uniform flow of water in streams and a constant supply in springs.

The water systems of many large cities depend for an unfailing supply of water upon streams which have their head waters in the mountains which are covered by forests.

When the trees are removed from a tract of forest and the land left uncultivated, the humus is easily washed away by heavy rains, for it is lighter than the soil lying underneath, and the roots which held it in place have been destroyed. This is the most valuable part of the soil for crops. The loss of this good soil is not the only evil which follows, however, for with the washing away (erosion) of the humus, streams form which soon cut channels into the subsoil, deeply erod-

ing it and making the tract unfit for cultivation. At the same time, the large streams and harbors are being filled with the soil which is carried down and deposited in them, and many of them become impossible to navigate unless they are constantly dredged. This is a costly process, and a needless one, if the knowledge we have were put into practice.

FIGURE 359. — WHAT DEFORESTING DID IN CHINA.

This represents the appearance of 200 square miles of once wooded mountains, which a century ago paid rich revenue on their lumber products.

Erosion can be prevented by planting crops or by reforestation. The roots of plants help to hold the soil, and the leaves which fall and decay year after year gradually forming a layer of humus make the land productive again in the course of a few years. Vast tracts of land which are now worthless for cultivation could be brought back to fertility by reforestation, and at the same time produce a crop of valuable trees which would regulate the flow of streams.

376. Attitude of the Early Settlers towards Forests. — When the settlers came to America, the forest on the eastern coast extended for about a thousand miles inland from the

FIGURE 360. — WHAT DEFORESTING IS DOING IN THE UNITED STATES.

A scene in North Carolina showing the rapid removal of soil after the forest is cut.

Atlantic, reaching to the treeless prairies of the central plain. On the western coast was a belt even wider extending from the prairies across the Rocky Mountains to the Pacific Ocean.

The first care of the settlers was to provide shelter from wild beasts and from the hostile Indians, and their second care was to secure a supply of food to last over the winter. To accomplish both of these, the destruction of trees was necessary. Trees furnished the most abundant and the most natural material of which to build houses and to make fuel, and they had to be removed before crops could be planted. Furthermore, they sheltered the settlers' enemies, so it was a matter of safety to have extensive clearings around the houses. Besides, trees were so plentiful that there was no need to be careful about using them. This attitude has been so thoughtlessly maintained that large tracts have been cleared for immediate profit or pleasure without thought of the future. Now the time has come when forests have to be conserved and additions made to them so far as possible, a condition which will become even more marked as the population increases and as the needs for wood and lumber become greater. Conservation does not mean locking up the products of forests to prevent their being used, but seeing that they are properly used and providing for a future supply. Conservation has become necessary on account of previous extravagance.

377. Lumbering. — This includes, primarily, cutting the trees, and getting them to the sawmill. Great waste has been characteristic of unscientific lumbering. This waste assumed two forms, injuring young trees in felling mature ones, and making use only of the most valuable part of the trees felled. The latter practice not only wastes much wood, that might be used in many ways, but it is also a menace to neighboring forests to have the dead, dry tops and limbs lying about to afford fuel for fire.

When lumbering is done scientifically, injured young trees are pruned and treated so that they may not become diseased by the entrance of spores of wood-destroying fungi, and all parts of the trees felled are either made use of, or the less

valuable are piled and burned under conditions which do not menace the safety of the remaining trees and which leave a clean floor, one of the best possible protections against forest fires.

378. Methods of Forest Protection. — Young forests, and old ones too, have their enemies. Fire, set by lightning

FIGURE 361. — FIRE SLASH.
The scene of a great destructive fire in 1908.

or careless smokers or campers, fungal diseases, made possible by accidents or careless pruning, and insect enemies, require that forests have supervision and attention to prevent damage and consequent loss to the owners. The persons who watch over forests in this way are called forest rangers.

The Work of a Forest Ranger. — A forest ranger has numerous duties, chief among which are to look out for fires and

to report them when they occur. As a prevention, campers and others are cautioned to be careful about letting fire spread, stations or lookouts are maintained from which a large territory can be surveyed for signs of fire, airplanes are also used to this end, telephone lines are kept in repair to provide for calling help to fight fire, roads are cut for the same purpose, and also with a view of making it possible to check the spread of fire by removing all brush and other material which will burn.

SALT LAKE FOREST RESERVE
ALL PERSONS MUST BE CAREFUL WITH FIRES
NOT LEAVE THEM BURNING USE ALL DEAD TIMBER
YOU NEED FOR CAMPING PURPOSES DO NOT CUT LIVE
TREES OF ANY KIND WITHOUT
PERMIT FROM RANGER

FIGURE 362. — SIGN CONTAINING WARNING ABOUT FIRES.

When fire occurs, it is fought by clearing paths at intervals, across which it cannot travel for lack of fuel. Trenches have the same effect. In some cases fires are beaten out with damp cloths or with branches of trees, and in rare cases, by the use of water. In some states regular trains are maintained on which are huge tanks containing water, and apparatus for throwing it some distance from the track. Prevention has proved more effective than any kind of device, however, and most efforts are being made in that direction. Signs and posters warn persons to be careful.

Campers are taught how to select a spot for a fire, how to care for it to prevent its being a menace, and how to put it out when breaking camp.

379. Forest Fires. — One of the most useless and unnecessary wastes of forest land is that caused by fire. Not only are thousands of dollars lost every year on standing timber, but the young growth also is utterly destroyed.

FIGURE 363. — THE RESULT OF HURRICANE AND FIRE IN IDAHO.

Of the forest fires in the United States during 1917, 7814 in number, 2132 were caused by lightning, and the others by human means, nearly all preventable; 952 were incendiary; 1288 were caused by careless campers; and 1003 by sparks from railroad locomotives, in violation of laws which call for spark arresters on engines used in or near the forests.

Forest rangers keep watch to see that fungus does not cause the death of trees, and to prevent the spread of

such diseases when they are found. In localities where cleared spaces in the national forests are rented for grazing purposes, forest rangers see that the regulations concerning the grazing of cattle are observed, collect fees, and otherwise serve as government agents. In some localities, the tract must be regularly patrolled to prevent the theft of valuable timber.

The life of a forest ranger requires good health and a love for the out-of-doors. It requires, too, at least a common school education, with special training to enable the ranger to recognize fungal diseases, and to estimate the quantity of timber on a tract or the lumber in a tree.

FIGURE 364. — CASTLE PEAK FIRE LOOKOUT.

380. Necessity of Reforesting. — So great is the value of forests that efforts are constantly being made to increase forest areas. Reforesting is necessary when tracts have been cut over or have been destroyed by fire. The state will coöperate when large tracts are to be reforested. There are three ways, the use of any one of which depends on local conditions. Seeds may be gathered and sown broadcast, but this is expensive and wasteful, as most of the seed is lost by falling on spots where it cannot grow, or is eaten by squirrels and birds. Again, it is not evenly distributed, and to obtain an even set requires additional work in transplanting.

Better results are obtained the second way, namely, by planting the seeds evenly and covering them to reduce the number that may be wasted. This is nearly as costly, and not so satisfactory as the third method, which consists of planting the seeds and raising the young plants in nurseries till they are old enough to live in the open. Then they are set out under favorable conditions, in large numbers, and

FIGURE 365. — NURSERY WHERE YOUNG TREES ARE STARTED.

allowed to grow with only such care as disease or injury make necessary.

381. Forestry and the Department of Agriculture. — The chief work in forestry of the United States is in charge of the United States Department of Agriculture. This is because the science of forestry is essentially a branch of agriculture, for it has to do with the growing of successive crops of timber from the soil.

The administration of the National Forests is directly in charge of the Forest Service, which is a bureau of the Depart-

ment of Agriculture. Its chief is designated the " Forester." Besides administering the National Forests, he supervises investigations in the best use of the forests and their protection.

The timber, water, grazing, recreational opportunities, and other resources of the National Forests are for the use of the people. These forests contribute to industrial enterprises through their yearly cut of over three quarters of a

FIGURE 366. — AIRPLANE VIEW OF EVERGREEN FOREST.

billion feet of timber, used mostly by sawmills and mines; they protect watersheds, which furnish about one third of the water-power resource of the country; they supply pure and abundant water to a thousand towns and cities; they furnish pasturage for nearly 15,000,000 head of livestock of all ages; and they afford playgrounds for millions of recreation seekers, to whom these vacation places are made accessible by the building of roads and trails.

In 1921 the total net receipts from the National Forests on account of timber sales, grazing fees, and special uses were $4,468,940.

382. Forestry in Other Countries. — The care of the forests in European countries began many years earlier than in the United States. This has resulted in a systematic organization of the forest work; in a greater interest in the scientific investigations of all forest problems; and in a deeper appreciation by the public of the value of forests. There one can study the results of many years of systematic planting and cutting. We have so many trees in this country that only slight attention has been given to utilizing all parts of the tree when it is cut. In Germany, Sweden, and Denmark the complete utilization of every part of the tree, down to branch wood one inch and less in diameter, is common practice.

There is still another feature of the forest development in Europe that is of interest. Many of the small villages own communal forests which belong to the people of the village. These are kept at a high state of production. They furnish the timber needed in the particular locality and afford a substantial income to the people.

383. Federal and State Protection. Parks. — The forests of the United States now cover about 550,000,000 acres, or more than one fifth of the total area. According to good authority these resources are sufficient to supply our lumber industries and firewood consumption, provided the area is properly stocked and conserved. This can best be done by the federal and state governments, which appropriate huge sums every year for the protection of forests and the development of parks.

Forestry in New York State. — The largest tract in this state is the Adirondack Preserve, which consists of about 4,600,000 acres. The next in size is the Catskill Forest tract of 1,200,000 acres. Smaller parks are the Long Island

Pine and Oak Lands, The Hudson Highlands, and Allegheny Highlands.

National Forest Preserves. — In 1891 President Harrison set aside the Yellowstone Park Timberland Reserve, which was the first forest preserve. Since that date other presidents have set aside other regions, until there are one hundred and forty-nine National Preserves with a total net area of over 156,000,000 acres.

384. Care of Trees. — Trees are subject to the attacks of fungal diseases and to the ravages of insects. Certain insect larvæ can be prevented from ascending trees by catching them under bands of burlap fastened around the trunk of the tree near the bottom, or they may be caught by bands of sticky paper fastened around the trunk. Insects which eat the leaves can be killed by a poison spray (see page 12), and those which suck the juices can be killed by a spray which clogs their spiracles (see page 66). Insect-eating birds like the chickadee, the wren, the nuthatch, the phœbe, and many others are the best friends a tree has. Birds should be protected and encouraged, for they are a great aid in fighting insects.

Tree Surgery. — Trees should be examined frequently for evidence of disease and injury from the elements and from insects. If dead or broken limbs are found, they should be sawed off smoothly as close to the trunk as possible, and the fresh surface painted over to prevent the entrance of spores of fungi or of bacteria. In case a tree has been split, its life may sometimes be greatly prolonged by bolting the parts securely together or surrounding them with a band of iron. Decayed parts should be cleaned out and the hole filled with cement to give strength and to prevent further decay. The scientific treatment of diseased or broken trees is known as *tree surgery*.

385. Trees in Parks and Streets. — Trees that are planted along streets, especially paved streets, do not thrive

unless special provision is made to enable their roots to obtain a supply of water and of air. This is done in some cities by covering an area with grating as far around the tree as possible and by systematic watering during dry weather. The grating is so made that it can be used as part of the sidewalk. Many fine old trees are killed every year by the injury done to their roots in grading for paving, and in depriving them of moisture by laying paving material which excludes water over a great part of the area occupied by their roots.

FIGURE 367. — HEMLOCK TWIGS AND CONES.

The importance of trees in parks and around homes cannot be measured. A few of the reasons why they should be planted are given, and you can add many more by a little thought. (1) Trees add greatly to the attractiveness of a locality or a home. (2) They furnish shade. (3) They increase the humidity of the air (see page 458). (4) They furnish homes for birds. (5) They increase the amount of oxygen in the air, and decrease the amount of carbon dioxide. The amount of water which is given off by a forest is sufficient to produce a noticeable effect on the climate of the immediate vicinity.

386. Some Common Trees. — The total number of kinds of trees in the United States is over 500, of which about 150 kinds are used as lumber. Each forest region has its few important trees, which can be readily learned.

The common trees in the United States fall into two general classes: (1) The narrow-leafed, cone-bearing, soft woods such as pine, spruce, balsam (the Christmas tree), hemlock, cedar, and others; in short, the evergreens. (2) The broad-leafed, non-cone-bearing, hard woods such as elm, maple, beech, oak, birch, basswood, and many others.

The use of the terms hard and soft wood is a lumberman's way of describing the difference between the two classes irrespective of the fact that basswood is softer than the evergreen long-leafed pine.

Shade Trees. — When one has occasion to plant a tree, the question often arises as to what is the best kind of tree to plant. While much depends on where the tree is to be planted, and on the care it will receive afterwards, there are a few general facts that should be kept in mind.

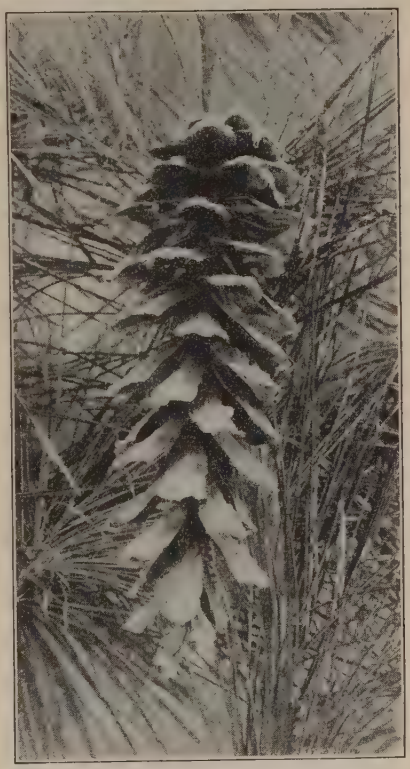

FIGURE 368. — WHITE PINE CONE.
There are five needles in a bundle.

Elm trees, poplar trees, and silver maple trees have the bad habit of clogging waste and sewer pipes in their search for water, of which they demand a large supply. Besides, one should consider that silver maple trees are brittle and apt to split when they

become old, and that their shade is light. Elm trees in some localities are subject to the attacks of elm beetles and require spraying to preserve them. Poplar trees are hard to kill when it becomes necessary to remove them, owing to their habit of sending up sprouts from the roots and from the stump.

Horse-chestnut and catalpa trees make a great deal of litter, detracting from their usefulness as ornamental trees. Other trees, like the Norway maple, have the habit of branching so low that they require frequent trimming in cities, to prevent their being in the way of umbrellas. The trimming is likely to mar their symmetry.

FIGURE 369.—TWIGS AND CONES OF NORWAY SPRUCE.

Commonly planted for ornament.

Hard maple, oak, sycamore, ash, linden, and tulip are satisfactory trees for most localities, having all the good features and none of the bad ones of the other trees mentioned. It should be remembered in planting trees along paved streets that the conditions are very hard, and they should have special care, otherwise they will die from much cutting of the roots and branches, from the attacks of insects, and from the lack of food and water. In planting, trees should have space enough left between them so that each tree may grow on all sides.

It is important that you should appreciate that these huge plants live in just the same way as small, even microscopic plants do. To make this point clearer, we shall give a short account of the pine and some of the evergreen trees.

387. Pine Tree as a Type. — The pine illustrates the plants of this family. The pine has all the parts of a flowering plant — stem (trunk), branches, roots, leaves, seed producing organs, and fruit (cones).

Stem. — The trunk does not divide, — a marked characteristic of conifers. In a forest where trees are crowded together and there is in consequence a struggle to get light, the trunks grow tall and most of the branches are near the top.

A cross section of a stem shows a series of rings, known as annual rings, by which the approximate age of the tree can be told. In the spring, when all the conditions are at their best and growth is rapid, the cells of the tree are large

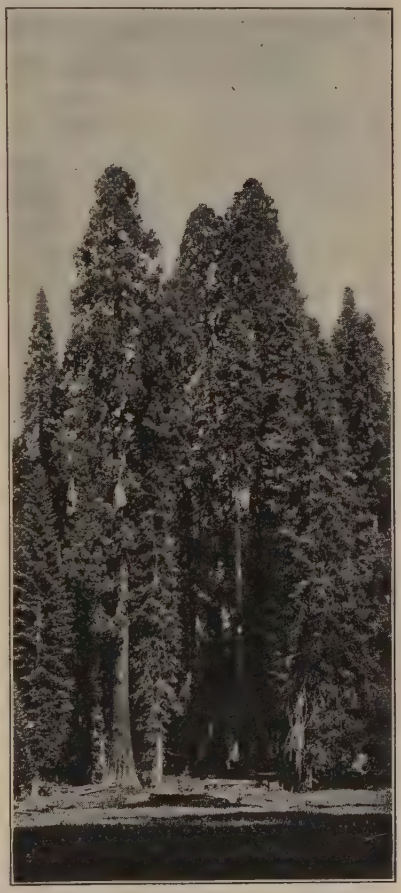

FIGURE 370. — A GROUP OF REDWOOD TREES.

This kind of evergreen grows best in the Rocky Mountains and west of them.

and thin-walled, strength being sacrificed to size. In the fall or during a dry time in summer, the cells formed are much smaller and the walls thicker. These small cells which show most plainly make up the annual ring. During a season in which long, dry periods occur, more than one ring may be made. From the center to the bark extend medullary or wood rays. The part of the stem where increase in thickness takes place is just under the bark.

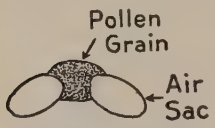

FIGURE 371. — POLLEN GRAIN OF PINE.

Branches. — The branches leave the stem almost horizontally and nearly in a circle around the trunk of the tree. In the pine they curve upward, but each kind of evergreen has its own habit of curvature in its branches.

Leaves. — The leaves, called needles, are long, slender, and flattened on one side. They grow in bundles of two, three, four, or five needles, according to the kind of pine. The leaves, which are borne but once in a place, remain on the tree from two to five years and then fall off, leaving the branches bare except near the ends.

FIGURE 372. — YOUNG OVULE-BEARING ORGAN (CONE).

Roots. — The roots of the pine vary according to the kind of pine and according to the soil, but they are always extensive.

Seed-producing Organs. — Early in the spring, two kinds of organs are found on the new shoots which grow from the terminal buds. The pollen bearers look like short catkins, and are borne in clusters near the base of the shoot.

They consist of scales arranged spirally around the central axis. Each scale bears two pollen sacs. They wither soon after shedding their pollen, although they may remain on the tree for a year. The other kind of organ, the ovule bearer, is short and thick, and is found at the tip of the shoot or on the side of the shoot near the tip. It, too, is made up of scales arranged spirally around a central axis. Each scale near its base bears two ovules. When the pollen is ripe, each grain, being provided with wing-like air sacs, is easily blown about by the wind. Some of the pollen sifts into the ovule-bearing organ (young cone) through the spaces between the scales, which at this time are separated slightly. Then the scales close up, the cones turn downward, and continue to grow for several months (Figures 372, 374).

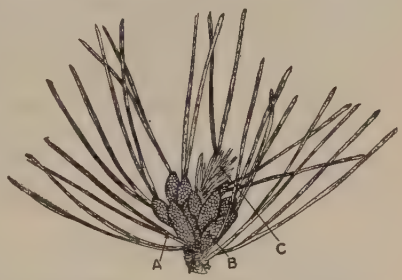

FIGURE 373. — YOUNG POLLEN BEARING ORGANS OF PINE.

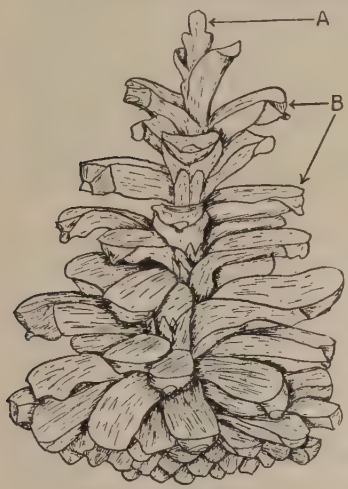

FIGURE 374. — MATURE CONE OF PINE.

Fruit. — During the next year, the pollen grains which are shut up inside the scales put forth pollen tubes and fertilize the egg cells which develop in the ovules. From the fertilized eggs the embryo pines develop.

When the cones are about two years old the scales open and allow the seeds to drop out. Each seed is provided

with a wing by which it is blown about, for the pine depends on the wind to scatter its seeds as well as its pollen.

388. Related Forms of Conifers. — Hemlocks, spruces, firs, and balsams have smaller, flatter needles than the pines and they are not arranged in bundles. Cedars have scale-like leaves. Larch and cypress trees shed their leaves in the fall, but in other respects are much like the pines.

Habitat. — The evergreens grow in sandy soil in temperate or in cold climates, but a few of them occur where it is very warm. The finest evergreen forests in the world are

FIGURE 375. — EVERGREEN TIPS, I.

Left, pine; upper center, fir; lower center, hemlock; right, spruce.

found in the western part of North America, on the slopes facing the Pacific Ocean.

Economic Importance. — The value of the conifers can scarcely be overestimated. Most of the trees are sawed into lumber for building purposes, but some of them are used in their natural form for telegraph poles, masts of ships, and timbers of mines. Wood pulp, from which most of our paper is made, is produced from small spruce trees. The by-products of this group of trees are of great value. From the pine come tar, pitch, turpentine, and resin, while the bark of the hemlock was formerly extensively used in tanning leather.

FIELD STUDY OR FIELD WORK

Most of the work in connection with conifers should be done out of doors. The student should learn to know by sight all the local native evergreens and those commonly planted for ornament. He should note the method of branching and the character of the trunk compared with other trees. He should observe the position of the cones on the branches and be able to give the reasons therefor. In the spring he should look for the male and female organs, and for leaf buds in the winter. He should examine the leaf scars and the external rings which mark a year's growth, and decide how many years each tree keeps its leaves. He should note the arrangement of the leaves on the branches,

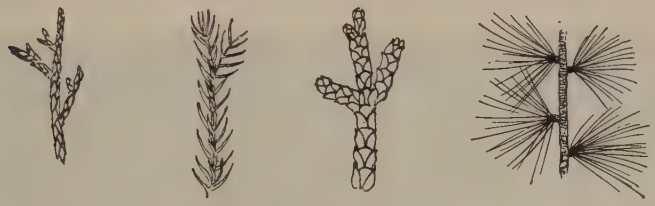

FIGURE 376. — EVERGREEN TIPS, II.

From left to right, (first two) juniper or red cedar, white cedar, larch.

the annual rings in the wood and their relation to the grain of the wood, the resin on wounds, the curvature of the branches, and other features readily observed.

Make a list of the trees you know by sight. What are the characteristics of each? What are they used for?

Make a list of all other trees known to grow in your locality.

STUDENT REPORT

	NEEDLES SINGLE ALTERNATE	NEEDLES SCALE-LIKE	NEEDLES IN BUNDLES	CONES LARGE	CONES SMALL
Hemlock .					
White Pine					
Larch . .					
Cedar . .					
Spruce . .					
etc. . .					

LABORATORY WORK

In the laboratory examine a cross section of the stem to see the difference in the cells grown in the early and in the late part of a season. Note the pith and medullary rays. If specimens are available, examine sections of wood from different trees. Make a collection of the woods found in the vicinity. Examine scales from staminate and carpellate strobili. With the microscope examine pollen of pine. Draw and describe all.

389. Properties of Wood. — The question may arise, What makes wood so valuable? Is there nothing else that

FIGURE 377. — SECTIONS OF WOOD.

Left, tangential section; center, cross section; right, radial section. Note the annual rings in all. The tangential and radial are most commonly used for lumber.

can be used in its place? One of its most valuable properties is that it is so easily shaped with sharp tools. Another is that it is light, compared with iron and steel, at the same time being tough and elastic. It has remarkable resistance to crushing, twisting, and pulling apart. A piece of yellow pine one inch wide and thick and a foot long supported at the ends, bears a load of 720 pounds without breaking. It requires a weight of 17,300 pounds to pull it apart,

and a load of 7,400 pounds to crush it. It is beautiful and it takes a high finish. The beauty of wood depends much on its grain, the closeness of which and the hardness of the wood determining its suitability for particular purposes. For instance, where wood-cuts are to be made, the grain must be very small, and the wood very hard. Holly and box are best for this. In the case of wood used for fork and shovel handles, the qualities desired are toughness and smoothness. These are found in ash and hickory, and so the list might be lengthened indefinitely. Balsa wood, newly discovered in the tropics, is much lighter than cork. This is employed in making life preservers and rafts to be used in case of accident at sea.

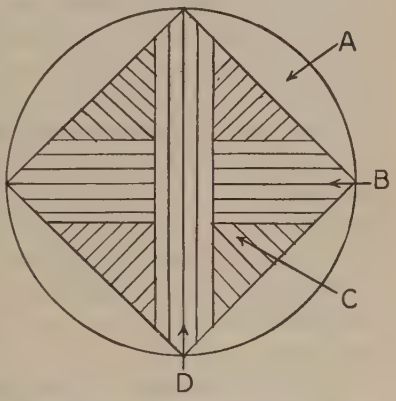

FIGURE 378. — DIAGRAM SHOWING HOW LOGS ARE QUARTER-SAWN.

A, slabs removed to square the log; *B*, *C*, short radial sections; *D*, long radial sections. Note that at least one end of every section is oblique, and that some of the sections are very small, entailing waste. Quarter-sawn lumber is used for furniture and interior finishing.

390. Preservation of Wood. — There are great differences in woods as to their ability to last in the soil or under water. Some, like cypress, cedar, and locust, have the ability to withstand decay on account of substances contained in the wood, such as resins. All wood lasts longer if it is seasoned, that is, allowed to dry out in the air before being used. Wood that is to be used in damp places, however, usually needs treatment to prevent or at least to retard the process of decay. As decay is caused largely by the work of bacteria or of fungi, both of which depend upon moisture as

one of their chief vital conditions, the use of timber thoroughly dried is one precaution taken to insure its lasting. Other methods used are charring portions that are to be covered by earth, and a third, the most common, is the use of chemicals. Railroad ties, for instance, are thoroughly impregnated with a solution containing creosote, among other substances, by being soaked in it for a long time, or by having it driven in under pressure. This acts as an antiseptic, preventing bacteria and fungi from growing in the wood, and prolonging the usefulness of the timber to a remarkable degree. Although treating ties in this way is costly at first, it is an economic measure on the whole, as it takes a smaller quantity of timber, and less labor than would be the case if the ties had to be replaced frequently.

Some kinds of wood depend for their beauty on the glistening medullary rays. These show to best advantage when cut lengthwise or obliquely, an effect obtained in quarter-sawn timber.

391. The Formation of Coal and Peat. — Ages ago ferns were more numerous than they are now, and many of them grew to be as large as our present trees. Geologists tell us that the climate was warmer and more moist than it is now, and conditions especially favored the growth of fern plants. Where these large ferns died and fell to the ground, great masses accumulated.

As the earth's surface changed, these masses became covered with soil or water, and under the influence of heat and pressure they, together with other plants now known to be primitive seed-bearing plants,[1] changed into coal. At the same time natural gas and petroleum, or rock oil, were formed. No coal is being formed at the present time, and

[1] In some cases, these trees have been found almost entire among the coal, and sections of them have been made for study with the microscope which are so thin that the cells and even the pollen grains can be studied easily.

when our supply is exhausted we shall have to find other sources of heat and power.

Peat, found in old bogs, consists largely of vegetable matter. When dried it can be used as fuel.

392. Forest Products. — A study of a few minutes will show that many articles of everyday use are made of wood. For instance, the paper on which you are writing was probably made from wood pulp; the pencil which you are using is made largely of wood; the table on which you are writing is of wood; the floor on which the table stands is made of wood; the walls of the house, or some part of them, are made of wood; the cars in which the lumber was brought to your city were made of wood; the ties on which the rails rested over which the cars ran were made of wood; the chair in which you are sitting was made of wood.

In some localities, maple trees are raised for the sugar and sirup which they produce. Chestnuts, hickories, walnuts, and others give us nuts year after year, as well as lumber when they are cut down. Willow trees give us a superior kind of charcoal used in medicine and in making certain kinds of gunpowder; the poplars and basswood or linden give us excelsior, so useful in packing fragile articles and in making cheap upholstery. Turpentine, obtained from the pine trees, is used in paint and varnish. Thin sheets of the more beautiful kinds of wood are laid over the cheaper or less beautiful kinds in the form of veneer. Wood alcohol, so useful as fuel, is obtained from wood wastes, like sawdust and shavings. Resin has many uses.

Perhaps the most extensive use of the forests is for lumber and fuel. White pine was formerly the kind of pine most in demand as well as the most abundant. Now yellow pine is taking its place on account of the scarcity and high cost of white pine, although yellow pine is slightly inferior. White oak is highly valued for interior finishing, floors, and furniture. Maple is a fine-grained, hard wood which is

much prized for furniture and other purposes. Curly maple and bird's-eye maple are valued as wood for veneer. The former has a wavy grain, and the latter numerous glistening points scattered through it, thought to be undeveloped adventitious buds. Black walnut, cherry, and mahogany are valuable for furniture. Hickory, elm, and ash are used for handles of tools and for parts of vehicles where toughness is required. Applewood, holly, and box are sought for turned articles. Cedar, larch, and cypress are used for posts and poles, and basswood for trunks and crates on account of its toughness, lightness, and elasticity. Poplar and catalpa, on account of their rapid growth, are planted where shade is desired in a short time.

One of the most valuable forest products is rubber, which is made from the sap of the rubber tree. The value of this product and the extent of its use are enormous. Boots, erasers, rain-coats, bands, automobile tires, and wire insulation are only a few of its many uses.

393. Forestry as a Vocation. — Forestry is the raising of repeated crops of timber upon soils unsuited to agriculture, and it has been extended to include the proper use of these forest crops. The science of forestry is so new that there is some difference of opinion as to the true definition.

We usually think only of large trees when we think of a forest, but it really includes all the life found in and upon the soil; trees, shrubs, herbs, and grasses are all parts of the forest life. Even expert foresters are unable to identify all of the kinds of life found in forests. The shrubs alone require many years of study. But all foresters must be familiar with most of the trees, and the specialist readily names each one.

To insure a thorough technical knowledge of the subject, colleges of forestry have been founded. Besides the theoretical training offered in the colleges, the men are taken

out into the forests for practical work under supervision. Such training affords great opportunities for men interested in this work as a vocation, and their service to the country can hardly be overestimated.

OUTLINE

- Importance of forests
  - Prevention
    - Of floods
      - By retarding melting of snow
      - By forming humus
  - Lumbering
    - For building
    - For fuel
    - Waste
  - Forest protection
    - From carelessness
    - From insects
    - Forest rangers
    - Forest fires
  - Reforesting
    - U. S. Department of Agriculture
      - Forest Service
      - National forests
    - In other countries
    - Federal and State protection
    - Parks
    - New York preserves
    - National preserves
  - Care of trees
    - Insects
    - Surgery
- Common trees
  - Evergreens
    - Pine
    - Spruce
    - Cedar
    - Hemlock
  - Deciduous
    - Elm
    - Oak
    - Maple
    - Birch
- Pine as a type
  - Stem
  - Branches
  - Leaves
  - Roots
  - Seed-producing organs
  - Fruit
- Related Conifers
  - Habitat
  - Economic importance
- Properties of wood
  - Light
  - Tough
  - Elastic
  - Beautiful
  - Useful
- Preservation of wood
  - Drying
  - Charring
  - Creosoting
- Formation of coal and peat
- Forest products
  - Pulp for paper
  - Building materials
  - Fuel
  - Saps
    - Maple sugar and sirup
    - Turpentine
    - Resin
- Forestry as a vocation

SUMMARY

Forests are of value to man for their products, for their influence in preventing freshets and erosion, in making soil, and in tempering climate. Forests are being used up so much more rapidly than new ones are growing, that conservation and reforestation are being practiced by both national and state governments. The enemies of forests are man's wasteful cutting, fire, and the ravages of insects and fungal diseases. Among their best friends are the foresters.

QUESTIONS

What is a forest? How are forests useful to man? Why is reforestation necessary? What is being done to conserve forests? What are the duties of a forester? What is forestry?

How are evergreens like other plants? How do they differ from other plants? What kind of trunk is characteristic of soft woods? How does a tree which grows in a forest differ from one which grows in an open field? Why? What are annual rings? How are they formed? Describe the branches; the leaves; the roots; the organs which produce pollen and ovules; the fruit. Name the evergreens. Make a list of the uses to which lumber is put. What other products come from the evergreen forests? In what ways are forests beneficial? What are the governments doing to protect them? What regions in your own state are covered with forests?

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CHAPTER XXXIII

FUNGI — PLANTS THAT LACK CHLOROPHYLL

Truth needs no colour. — SHAKSPERE

394. Fungi. — The fungi are of importance to us because: (1) some can be used as food (the so-called mushrooms); (2) one of them, the yeast plant, is used in making bread; (3) others spoil our food, as when they grow on bread and cake; (4) they cause many diseases in plants.

Fungi differ from most other plants in two respects. (1) They are colorless, or nearly so, chiefly because they have no chlorophyll. (2) They are dependent for food on plant or animal substances, either dead or alive, because they lack chlorophyll and hence cannot make their own foods as the green plants do.

Fungi which live on the substances or juices of live plants or of animals are called *parasites* (Greek, *para*, beside; *sitos*, food); and those that live on dead plants or animals are called *saprophytes* (Greek, *sapros*, rotten; *phyto*, plant).

Distribution of Fungi. — Fungi are to be found wherever the conditions for their growth are favorable, namely, in damp warm places where they can obtain organic food. A dim light favors their growth in many cases. The spores remain viable for a long time, and their lightness causes them to be widely distributed.

395. The Yeast Plant. — This plant is a unicellular fungus, too small to be seen by the naked eye. It is oval or almost round in shape, and nearly colorless. It has all the parts

of a typical cell, although the nucleus cannot be seen without a special stain. Because it lives upon dead vegetable matter, it is a saprophyte.

The Work of the Yeast Plant. — In the making of bread, we know that: (1) yeast secretes an enzyme which breaks up sugar into simpler substances; (2) in this process alcohol is formed and carbon dioxide is set free; (3) the yeast lives on the protein substances in the flour; (4) both the gas which makes bread light and the alcohol are driven off by the heat of the oven when the bread is baked.

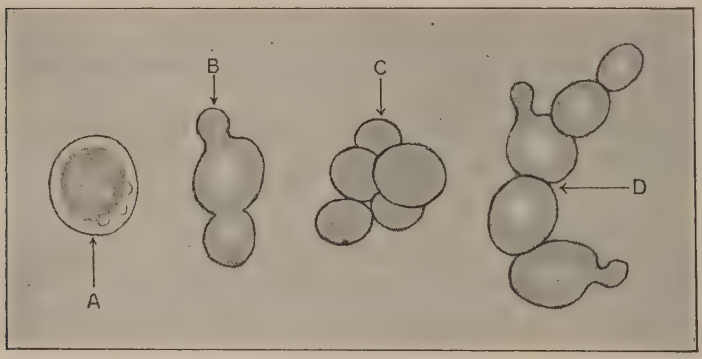


FIGURE 379. — YEAST PLANTS.

A, single cell; *B*, cell with buds; *C*, group of cells; *D*, chain of cells.

Yeast, like all other rapidly growing plants, produces and uses vitamins in large quantities. For this reason it is a valuable source of these substances because from it they can easily be obtained in a cheap form. Before the action of bacteria and yeast were understood, much trouble was experienced in getting uniform products, owing to the presence of undesirable bacteria and yeasts. The possibility of making pure cultures, the use of the microscope, as well as the tests which are made in the laboratories at every step of the manufacture, have placed the bread-making industry on a scientific basis.

Reproduction of the Yeast Plant: Budding. — The method of reproduction of the yeast plant is similar to that of the bacterium, but differs from it in that instead of dividing exactly in two, a bud usually pushes out from the side of the mature plant. Sometimes the second plant forms a bud before it breaks away from the first, and so a chain of buds is made. Often a single plant puts forth more than one bud (Figure 379).

FIGURE 380. — FERMENTATION TUBES.

The bulb is filled with nutritive liquid containing yeast plants. As they grow they form carbon dioxide gas, which collects in the bulb, forcing the liquid into the upright arm. These tubes are used in estimating the number of yeast plants in a substance and the rapidity of their growth. In water analysis, the formation of gas with certain media indicates pollution.

LABORATORY STUDY

Prepare a Pasteur solution, a good food for yeast, as follows:

Potassium phosphate	10 parts
Calcium phosphate	1 part
Magnesium sulphate	50 parts
Ammonium tartrate	50 parts
Cane sugar	750 parts

Sufficient water to make a total of 5000 parts. (This may be used for the culture of other molds than yeast and also for bacteria.)

Yeast. — Examine yeast cells under low power. Note their glistening appearance and their number. Under the high power try to find all parts of a typical cell. Label and draw. Look for budding cells and chains of cells. Draw. Make a thick paste of water, yeast, and flour. Put an equal amount into each of three tumblers. Place one tumbler in a cool place. Into one of the remaining tumblers stir a teaspoonful

of sugar and set both in a warm place. Examine several times a day and write down all the differences you observe in the three mixtures. Try to give a reason for everything you observe.

396. Bread Mold. — When examined with the naked eye, bread mold appears like a thick mass of felt, made up of colorless, closely interwoven threads. These threads are called *hyphæ* (hī'fē : Greek, *hyphe*, web) and are of two kinds, one lying on the surface of the bread or just below it, and the other standing upright above the surface. The first are the nutritive hyphæ, which digest and absorb food ; and the second are the reproductive. On the ends of the latter

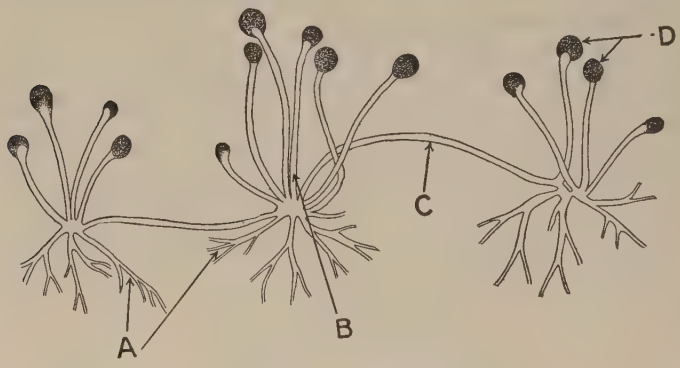


FIGURE 381. — BREAD MOLD.

A, nutritive hyphæ; *B*, spore-bearing (reproductive) hyphæ; *C*, stolon; *D*, sporangia.

are round black bodies which are full of spores, each of which is capable of producing a new mold plant, if it falls into a place where conditions are favorable for growth, — that is, where it has plenty of food, the right degree of warmth, and sufficient moisture. Other kinds of fungi may usually be found on a loaf of bread after a day or two, as spores of many kinds of molds are floating in the air at all times (Figure 381).

LABORATORY STUDY

Wet a piece of bread, put a tumbler over it, and set it in a warm place for three or four days. Examine without the microscope to get the general appearance. With the microscope note (1) the clear, colorless threads (hyphæ) making up the mass; (2) the groups of spore-bearing bodies, black and round, on the ends of the upright stalks; (3) the spores coming out of them.

397. Economic Importance of Fungi. — We have seen how fungi may be helpful like yeast, or harmful, like mold. While some fungi, like edible mushrooms, are useful economically, most are harmful. Among these may be mentioned various rots, potato blight, red rust of wheat, corn smut, which produces the black mass found in an ear of corn, and the bracket fungi, which grow in large numbers on trunks of trees and whose hyphæ cause the death of the tree.

FIGURE 382. — COMMON FIELD PUFFBALL.
This is in condition for picking when the inside is white. (From Murrill's "Edible and Poisonous Mushrooms.")

The fungi used for food are nourishing, but there is a prejudice against their use because other fungi which resemble them closely are poisonous. As a matter of fact, it is an easy task to learn to distinguish the edible from the poisonous fungi. While the harmless fungi are now used as food much more than formerly, only a few varieties are raised for trade purposes (Figures 383 and 384).

Plant Diseases. — Because of their importance we are going to choose three typical plant diseases, Cabbage Yellows, Potato Wart, and Black Stem Rust, and study them to see how the fungi destroy our food plants. As you learn about

each of these diseases, you will see that it is much more important that the disease be prevented than cured. Note the kind of knowledge necessary to recognize these fungi and the methods used in treating them. In the case of the rust, your attention is called to the complicated life history of this fungus parasite as it lives first on the wheat, and then on the wild barberry in a never ending cycle.

FIGURE 383.—SHAGGY-MANE (COPRINUS COMATUS) IN PERFECT CONDITION FOR PICKING. (From Murrill's "Edible and Poisonous Mushrooms.")

The farmer who would be successful must learn how to recognize the common diseases of farm plants. If he does not know about this important part of farming, he can ask the Agricultural Experiment Station to tell him what he ought to know.

398. Cabbage Yellows. — This disease is caused by a soil fungus, *Fusarium conglutinans*, which is not known outside of the United States.

Effects. — The fungus attacks the roots of the plant either in the seed bed or soon after transplanting. It works greatest havoc during a hot, dry period, as warm soil favors its growth. The plants attacked soon become stunted and the foliage assumes a pale, lifeless, yellow color. The disease is often more severe on one side of the plant than the other, causing it to curve towards that side. The fungus enters through the roots and passes up to the stem and leaves through the vascular bundles, which it soon clogs and destroys, as well as the tissue adjoining it. As the destruction of the vascular bundles shuts off the plant's sup-

ply of food material and water, the lower leaves soon drop off through lack of sustenance, and the whole plant either becomes sickly and fails to head or dies outright, according to the severity of the attack.

Destructiveness. — On fields moderately infected, from 50 to 75 per cent of the crop is a loss, while in badly infected fields the crop is a total failure.

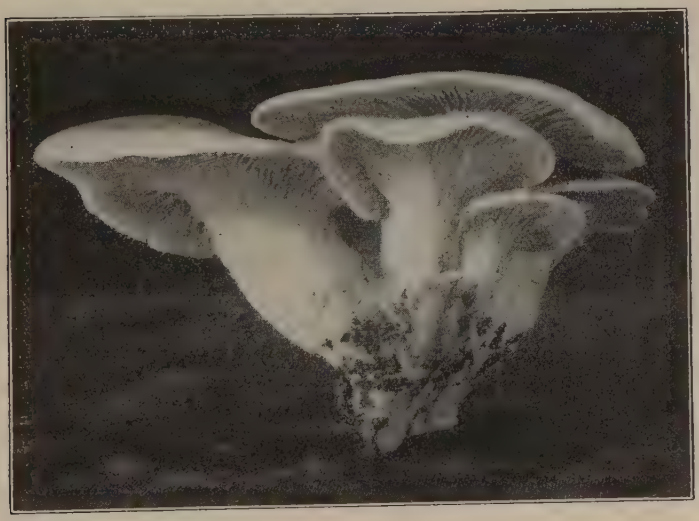


FIGURE 384. — OYSTER MUSHROOM.

An edible mushroom which grows on wood. (From Murrill's "Edible and Poisonous Mushrooms.")

How the Disease Is Spread. — The fungus is carried from field to field in a variety of ways: for example, (1) by diseased plants from infected fields; (2) by water which drains from infected fields; (3) by wind blowing the dust from field to field; (4) by vehicles, tools, and animals.

Persistence. — Once introduced into the soil, it remains for long periods, experiments extending over fourteen years having shown it to be still present and active. Soil infested

with this fungus is said to be " cabbage sick," but other crops grow well in it.

Control Measures. — Various measures have been tried as a means of controlling the disease: (*a*) Disinfection of seed and seed beds. This failed because the fungus was in the soil of the field and not on the seeds or in the seed beds. (*b*) Using new land for seed beds. This failed for the same reason. (*c*) Crop rotation, to give the fungus a chance to die out. A period of fourteen years was found to be too short, so that also was impracticable. (*d*) Fertilization of the soil with a view to obtaining such vigorous plants that they could resist the disease. No success was attained. (*e*) Soil disinfection, for the purpose of ridding the soil of the fungus. Nothing was found that was cheap enough or that would kill the fungus without being detrimental to the growth of the crop. (*f*) Finding plants able to resist the disease, based on the experience of finding now and then a head in a whole field that had been able to live when the rest were killed.

The method used was to take such heads and raise seed from them for next year's crop. These plants were found to produce a higher percentage of resistant plants, the best of which were then selected to produce the seeds for another crop. In this way strains have been developed that are practically immune to the attacks of the fungus. Much still remains to be done, but enough has been accomplished to make sure that success in combating the disease lies in producing disease-resisting plants. No one has yet discovered what the differences are that make immunity possible in one plant and not in another.

399. Potato Wart. — This is a disease dangerous to the common potato which has been known in Europe for many years, but which has been found in the United States only since 1918, when it was discovered in Pennsylvania. It was introduced on an importation of several millions of bushels

in 1911, which were distributed over the eastern part of the United States. Much attention is now being given to locating centers of infection, in order that quarantines may be established.

Signs of the Disease. — The effects are found in the potato itself and not on the parts above ground, which accounts for its not being discovered till harvesting time. The first evidences of wart are small spongy outgrowths on the surface of the potato, especially at the eyes. Sometimes warts arise on different parts of the same potato, transforming it into a spongy mass which turns from brown, the first color, to black, then decays (Figure 385).

FIGURE 385. — POTATO WART.

What Causes Wart. — Wart is caused by a fungus which penetrates the outer coat of the potato and stimulates the cells to abnormal growth. When the wart decays, it fills the soil with millions of sporangia of two sorts, one capable of germinating at once and infecting new potatoes or new places on the same potato, and the other resting sporangia, capable of living over the winter and starting the infection anew in the spring, or lying dormant for years until conditions become favorable for germination.

How the Fungus May Be Spread. — (1) By drainage from infected fields; (2) by distribution of the infected soil; (3) by the use of manure of animals which have eaten the

raw potatoes; (4) by garbage into which peelings from diseased potatoes have been thrown; and (5) by planting diseased potatoes or those which have grown in infested soil and carry the spores on their surfaces.

Control of the Disease. — As the result of many experiments with disinfection, fertilizers, resistant varieties, and so forth, the best means of control seems to be to destroy or boil all potatoes grown on such infested land, to establish a strict quarantine to prevent its spread, and to practice rotation of crops over the period of eight years that the fungus is known to remain in the soil. It does not cause damage to any other cultivated crop, but it may propagate itself on other members of the potato family, especially such as grow wild.

Note. — As an illustration of the application that may be made of biology, it is said that the disease was first reported in this country by a biology student in high school who had noticed potatoes in the field at home, but had not known the cause of the peculiar appearance or the seriousness of the disease till his teacher mentioned it in class.

400. The Black Stem Rust of Grain and the Barberry. — The black stem rust of grain causes the loss of millions of bushels of grain every year. In 1916, a bad rust year, the loss in wheat alone in a single state, Minnesota, was about 30,000,000 bushels. In 1917, not a bad rust year, the loss in the whole United States was about $1\frac{1}{2}$ per cent of the whole crop. The wheat affected by rust has shrivelled grains, which are light in weight, and straws which are crinkled and broken.

The Causes of the Rust. — This is a fungus which lives as a parasite on the stalks and heads of grains and grasses during a part of its life history, and on the leaves of the common barberry for the other part. This is spoken of as the alternation of hosts, a habit which is characteristic of several other fungi which cause plant diseases.

How It Spreads. — The fungus itself is composed of very small threads or hyphæ which grow inside the leaves and stems of the host plant. It spreads from one wheat plant to another by means of spores which are carried by the wind, insects, or other means. In the early part of the summer these spores appear in red pustules on the stems and leaves of the infested plants, from which they fly like dust when the plants are disturbed. On account of their small size and large numbers, they fall on other plants, some near at hand, and some long distances away. When moisture makes it possible, each spore sprouts and forms a new center of infection. These spores, called summer spores, are red or orange colored and egg-shaped. In the autumn another kind of spore is produced, namely, the black or winter spore. These appear in black pustules on the stems and leaves of the plants which serve them as host. These spores are longer, and have thick walls, an adaptation which enables them to live over the winter in stubble and straw. They are made up of two cells, and usually are not carried by the wind.

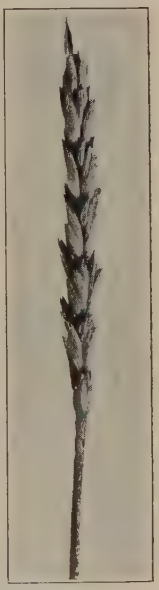


FIGURE 386.—A DISEASED HEAD OF WHEAT.

The dark spots are fruiting bodies of the rust.

When they germinate in the spring, each of the two parts produces four round, colorless bodies called *sporidia*. These are blown about by the wind, but they are not able to propagate the disease unless they fall upon the barberry, where they produce a plant so different in appearance that it was for many years considered a separate plant and given a different name. On the leaf or fruit of the common barberry, the sporidia produce yellow circular spots containing reddish spores in long chains. From the shape of the spot, this is often called the cluster cup

stage. This stage is most active from May until midsummer. The spores from the plant on the barberry cannot reproduce on the barberry, but on being blown to the grains or certain grasses, they begin a new stage in the life history of the red rust. These propagate on the grain in the field as before. Another source of infection is the summer spores which may have lived over the winter on the grasses near the field, or on straw or stubble. A summary will put the history clearly: (1) the red or summer spores spread the disease from wheat to wheat, or from wheat to grasses and back to wheat; (2) the winter spores formed on wheat or grasses in the autumn remain on them until spring when, by means of sporidia, the infection of the common barberry takes place; (3) the cluster cups or spring spores on the barberry start the infection again on the wheat and grasses.

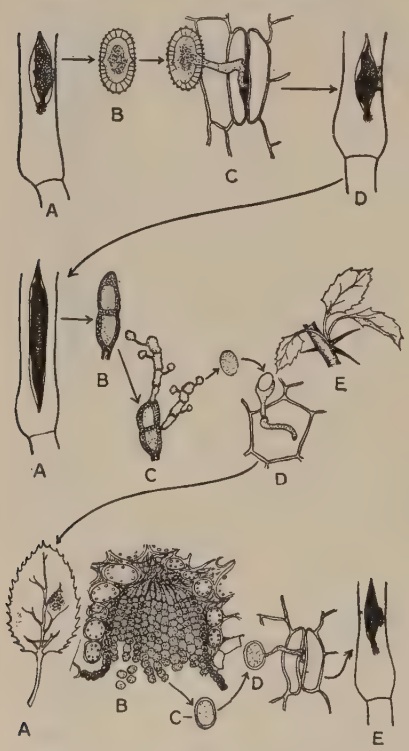


FIGURE 387. — DIAGRAM OF LIFE HISTORY OF RED RUST OF WHEAT.

Conditions Favoring the Rust. — Cool nights with heavy dews, followed by hot muggy days, afford ideal conditions for the growth of the disease. Any condition which favors the growth of the grain and retards that of the rust is unfavorable to the disease.

Methods of Control. — No sure means has been found of curing the disease, but experiments have proved that there are several ways of reducing the amount of damage done by it. Among them may be mentioned clean cultivation, which gets rid of the grasses on which it grows; planting early varieties of grain which mature before the rust has time to develop; planting varieties which have been found able to resist the disease; and, best of all, getting rid of the common barberry. Denmark, which eradicated the barberry in 1903, has not had an epidemic of rust since.

Note. — The Japanese barberry, more commonly planted for ornament than the common barberry, is immune to the rust, and may be spared.

HOME WORK

Make a list of the plant diseases you know. Try to find out what causes each and how it injures the plant. Make a list of the remedies you know of for each disease, such as sprays. Find out from the owner of a farm how many bushels of each crop his land produced to the acre. Compare this with the average for the United States. Account for the difference. What can be done to improve a low yield?

We close the study of the simplest plants with the fungi. As in the case of the bacteria, men have spent their lives studying the fungi, especially those which cause disease. Much has been accomplished, but a great deal remains to be done in finding out the cure for certain fungus diseases, especially those that attack vegetables which we use for food.

OUTLINE

- Fungi
  - Kinds
    - Useful
      - As food
      - In making bread
    - Harmful
      - Spoil food
      - Cause disease
  - Characteristics
    - Colorless
    - Dependent on organisms
  - Distribution
    - In warm, damp places
- Yeast
  - Unicellular

- In bread
  - Breaks up sugar
  - Forms alcohol
  - Gives off carbon dioxide
  - Lightens bread
- Vitamins
- Reproduction
  - Budding
- Bread mold
- Hyphæ
  - Nutritive
  - Reproductive
- Economic importance of fungi
- Helpful
  - Yeast
  - Some mushrooms
- Harmful
  - Rusts
  - Rots
  - Blights
  - Smuts
- Cabbage yellows
  - Effects
  - Destructiveness
  - How spread
  - Persistence
  - Control
- Potato wart
  - Signs
  - Cause
  - How spread
  - Control
- Black stem rust
  - Cause
  - How spread
  - Control

SUMMARY

Fungi are of great importance. While some, like certain mushrooms and yeast, are useful, most of them are harmful. Yeast is invaluable in making good bread, but other fungi, like bread mold and all the various rusts, blights, and smuts, do great damage to living organisms. Among the worst of these are (1) cabbage yellows, which have been found almost impossible to exterminate, (2) potato wart, which ruins many a potato crop, and (3) black stem rust, which causes the loss of millions of bushels of wheat each year.

QUESTIONS

What fungi are useful? Which ones are harmful? Can you tell edible from poisonous mushrooms? What are the characteristics of fungi? Where do they grow best? How does yeast affect bread? Did you ever eat any unleavened bread? How many ways have been tried to fight cabbage yellows? Describe some of them. How can potato wart be controlled? How much damage does black stem rust cause each year? How does it spread? How can its ravages be reduced?

CHAPTER XXXIV

PLANT CULTURE

Where grows? Where grows it not? If vain our toil,
We ought to blame the culture, not the soil.

— POPE

401. Relation of Soil to the Growth of Plants. — We have seen (page 540) that it is possible for seeds to germinate without soil, and laboratory experiments have been made in which

FIGURE 388. — PEACH ORCHARD ON RECLAIMED MESA LAND.

plants grew in water to which had been added the substances necessary for their growth. Under ordinary conditions, however, soil is absolutely necessary for the healthy growth of most land plants. There are two main reasons for this.

First, plants need soil to anchor them. How effectively even small plants are anchored can be proved by trying to pull a weed a few inches high with only one hand. When you think of the great weight of some plants, for example, trees, you can see how strong their roots must be and how deeply they must penetrate to resist the weight and the force of the wind against the tops.

Second, plants need soil to hold moisture for them to absorb, and to furnish the minerals needed for growth. The only way they have of obtaining them in nature is in water which dissolves small quantities of them. Since soil furnishes certain elements that cannot be obtained elsewhere, and since it is necessary to enable plants to stand erect, it follows that there is a very close relation between the character of the soil and the elements it contains and the successful growth of plants. This is especially true of cultivated plants. Therefore, a farmer studies the kinds of soil and the plants best suited to grow in them, and also the best ways to prepare the soil to make it of the greatest help to the kind of crop he is planting.

402. Kinds of Soil. — Soils differ not only in the elements which they contain (we speak, for instance, of an *acid soil* or an *alkaline soil*) but also in the coarseness or fineness of the earth.

Another classification is based on texture, four grades serving as a basis for the description. The coarsest is *gravel*, composed of small, usually round, stones. This is the poorest kind for most plants as it does not hold water well. Somewhat better in the matter of holding water is *sand*. Irrigation has made thousands of acres of sandy land productive, as water can be supplied whenever it is needed.

Loam is fine sand which is mixed with a large quantity of decayed organic matter known as *humus*. This is one of the best kinds of soil for retaining water. *Clay* is very fine, hard-packed soil which retains water well, if it takes it up.

It is often too firm for the roots of plants to penetrate to get the water. Many other kinds of soil might be mentioned, but they are all a combination of the four described. *Muck* consists almost wholly of decayed organic matter.

403. Preparation of Soil. — Farmers prepare the soil by breaking it up, thus allowing the roots to penetrate it easily (see page 490). Plowing, harrowing, raking, dragging, and spading are the methods used, according to the size of the plot cultivated.

FIGURE 389. — IRRIGATING DITCHES.

The humus which lies near the surface and is spoken of as *surface soil* must be thoroughly mixed with the *subsoil.* The depth to which soil is plowed and the degree of fineness to which it is reduced are determined by the kind of crop to be planted and the amount of cultivation it can receive while it is growing. In any case the soil must be loose enough for the roots to penetrate it easily, for it is from the soil that they gather moisture and food material for the plant.

Often the preparation of soil includes a thorough mixing of fertilizer with it. In some cases also land is so marshy that it has to be drained before it can be plowed.

404. Seed Selection. — Farmers who try to secure full returns for the labor expended make it a point to select seed carefully. In several states granges and other organizations offer courses of instruction as to what constitutes good seed, and form clubs among the boys and girls, who compete for prizes for yields of superior quantity and quality from selected seed.

Corn can be used as an example of the way in which seeds are selected for planting. First, care is taken to save for seed ears that are of the right shape and of the right size, usually the largest ones, and those that have the grains developed at both extremities. This may be called an ideal ear. An ideal ear for one variety is not necessarily so for another.

Dormancy. — Most seeds have a rest period, or *period of dormancy* as it is called. This is longer in wild plants than in cultivated ones. In most seeds the dormant period is only from the summer of one year to the spring of the next.

In pigweed, however, the seeds of any one year may require several years for development, owing to differences in the thickness of the testa. Those grow first which have the thinnest testa. Years may pass, therefore, before all the seeds of a single crop have grown. This fact and the great number of seeds produced are the two main reasons why this weed is so persistent. Once it has seeded, it has the ground supplied with seeds that will grow some one year hence, some two, and so on up to thirty years.

Other weeds which produce seeds that can lie dormant for at least thirty years are shepherd's purse, black mustard, chickweed, and curly dock. Variation in the thickness of the testa in seeds on the same plant is an adaptation which prevents the plant from dying out even if unfavorable conditions cause the death of all the seedlings of any one year.

Closely related to the dormancy of a seed is its *viability*, or power to grow after long periods of rest. It has been proved by experiments that the seeds of weeds mentioned

above are viable or able to grow after a dormancy of thirty years. Such facts as have been established by experiment lead us to discredit stories about the growing of seeds that have lain in Egyptian tombs hundreds of years.

Seed Testing. — This is necessary, since it has been found that mere appearance is not a safe guide in selecting seed, for great difference exists in the viability of different ears (see page 588). To test viability, a few grains are taken from the base, the tip, and the body of an ear of corn, or from hundreds where testing is done on a large scale. These grains are all placed under the same conditions for germination, as nearly perfect as possible (see page 541), and careful records are kept of the results. Only those ears are saved for planting which show a high percentage of germinating grains. In the case of oats and similar grains, the seeds are counted and a record kept of the number which germinate. Any kind of seed can be tested in the same way. Old seeds should always be tested to save disappointment. (See page 588, Viability, and page 527, Use of the Terms Fruit and Seeds.)

405. Methods of Planting. — These vary with the nature of the plant, the use to be made of it, and the region where it is grown. For instance, corn is usually planted in "hills," that is, a few seeds (grains) are dropped into a slight depression, and the soil is heaped over them. As the plants grow, more and more soil is hoed around the bases of the group of plants in a hill. This favors the sprouting of prop roots (see page 491), and enables the plants to stand firmly against winds.

When seeds are sown in "drills," they are dropped one in a place in a thick or thin line, according to the kind of grain and the condition of the soil. Garden seeds are planted in drills, also. Drilling is usually done by a machine which can be regulated to suit the size of the seed and the depth and thickness of the planting desired.

Corn must always be planted close enough to secure thorough pollination if full ears are wanted, for only those ovules develop which have been fertilized by the growth of a pollen tube through the length of the long style, the silk. As sweet corn does not mature all at the same time, it must be planted far enough apart to permit a man to walk between the rows with a basket to select the ears which are ready to be picked.

FIGURE 390.—A FIELD OF CORN. *From Nature Magazine.*
The plants are close together.

Corn planted in hills or in drills far apart grows to large size and bears many ears. The object in planting by this method is to secure a large yield of grain.

When the plants themselves are to be used as ensilage and a large production of leaves and stalks is the end sought, drilling is closer and the stalks grow taller and not so stout. In warmer regions where growth is more robust, only the leaves and the upper part of the stalks can be used as food for cattle, especially after the crop has been planted with a view

to securing many ears. The method here is to plant one seed at a time, with distance enough between the plants to give each one a chance to grow to the fullest possible size, and to produce large leaves which are stripped from the stalk at the end of the season after the ears have been gathered.

Small seeds must be sown in very shallow drills, and larger ones in deeper drills or furrows. Some seeds absorb moisture readily lying loosely in the soil. Others need to have the

FIGURE 391. — FIELD SOWN IN DRILLS.

earth pressed firmly over them to make absorption of moisture more rapid and certain. This is often accomplished by passing a heavy roller over the soil where wheat, oats, and similar grains have been sown in drills.

Besides knowing how each kind of seed ought to be planted, a successful farmer must know what soil is best suited for each crop, and also the time of year to plant it. Some seedlings are easily killed by frost, and others are not harmed by it. More and more it is becoming necessary for the man who raises plants to have a knowledge of plant life in general.

406. Necessity of Cultivation of the Soil. — When crops appear above ground, many of them, corn for example, must be cultivated. In cultivating, three objects are kept in view: (1) to keep the soil loose enough for the roots to penetrate it easily; (2) to conserve moisture; (3) to kill weeds.

Humus is the most important part of most soils, since it contains raw material in abundance and in a form to be easily used by the plants. It also helps the soil to soak up and retain water much as a sponge does. Proper cultivation helps to

FIGURE 392. — A DESERT SCENE.
Even with cultivation it is hard to raise crops here.

retain water that would otherwise be lost through evaporation from the surface, even in soils which contain much humus.

Irrigation. In the United States most of the cultivated land depends on rainfall for its supply of water. In the west, however, irrigation supplies the water needed (see page 596). In the Old World, irrigation is used to raise the crops which support millions of people.

Thinning and Transplanting. — Crops like garden vegetables will not grow to full size unless each one has sufficient room. On the other hand, a greater yield can be secured

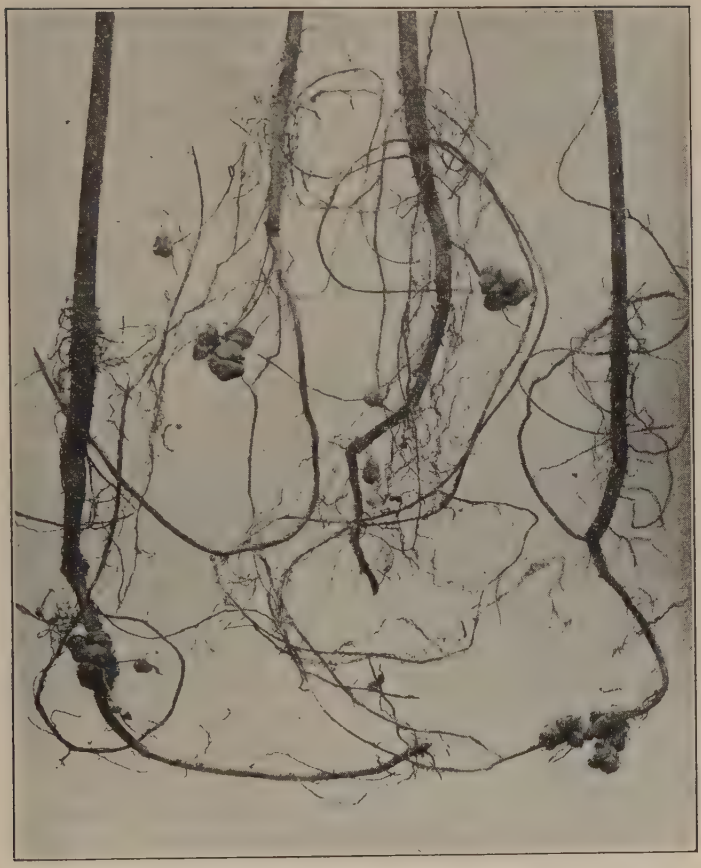


FIGURE 393. — NODULES ON ROOTS OF BEAN PLANT.

by transplanting to fill all vacant spaces. Transplanting tomatoes, peppers, and other plants grown in greenhouses makes it possible to secure ripe fruit earlier than if they were first planted out of doors after danger of frost.

407. Soil Exhaustion. — Every plant that grows in the soil takes from it some of its substances — iron, sodium,

phosphorus, etc., especially nitrogen, which occurs in the form of nitrates. After a few years the soil becomes so lacking in substances which plants require that a profitable crop cannot be grown. Such soil is worn out or exhausted. It cannot produce good crops till the lack is supplied. This is usually done by adding fertilizer which contains nitrogen, the element which is used in greatest quantity. Nitrogen can be obtained in several ways, chiefly three: (1) by bacteria on the roots of leguminous plants (see page 394); (2) by using the wastes of animals, especially urea, which contains it; and (3) directly from the air by a new process.

FIGURE 394. — NODULES ON ROOTS OF PEANUTS.

The Nitrogen Cycle. — Nitrogen is taken into the body of a plant through the root hairs, and built up into protein. These plants are eaten by animals, which use part of the nitrogen to build up their cells and get rid of the excess through their kidneys, if they are higher animals. When the body of any organism decomposes, nitrogen is returned to the soil and ultimately to the air again, thus completing the "nitrogen cycle."

The Use of Fertilizers. — The term *fertilizer* covers substances used not only to replace those taken from the soil by

plants, especially crop plants, but also those which are added to make the elements already there more available. Manure, usually mixed with urine, is rich in organic matter. It furnishes material that can be readily appropriated by the plants, and also improves the quality of the soil for holding moisture. Guano is the refuse of millions of sea birds which has accumulated through the centuries. Bone meal is a third form of fertilizer which helps to provide nitrogen

FIGURE 395. — DESERT LAND.
No cultivated crops can grow here.

for plants. Nitrates dug from the earth in some localities is another form in which this element is supplied to soils in which it is lacking. Lime, wood ashes, and other substances help to overcome the acidity which prevents the growth of some plants. Phosphates added to the soil make it possible for plants to obtain phosphoric acid, a form of phosphorus which can be utilized in building up protein.

By a newly perfected process, nitrogen can now be taken directly from the air and prepared for use as a fertilizer. Inasmuch as the quantity in the air is so small — four parts

in ten thousand, this can be done with profit only where there is abundance of cheap power, usually water power.

408. Irrigation and Dry Farming. — This is carried on in the western United States where the rainfall is so scanty that only a few plants especially adapted to extremely dry conditions (see page 492) can live. This region, although now a desert, lacks only water to make it productive. The water

FIGURE 396. — IRRIGATING DITCH.

for irrigation is secured by building dams in suitable places and storing throughout the summer the water from spring freshets and melting snow on the mountain peaks.

Closely connected with this phase of land conservation is *dry farming*, so called. This is possible, as strains of wheat and other crops have been found which can grow with much less moisture than the ordinary kinds demand. The use of such strains makes crops possible on land too dry for farming under ordinary conditions.

The use of water for irrigation has been practiced from very early times, especially in India and Egypt. The methods used there, and the results obtained, however, are insignificant when compared with modern methods, a good example of which we find in the western United States. Immense dams are constructed which impound lakes covering many acres. The water from these lakes is let out, carried miles

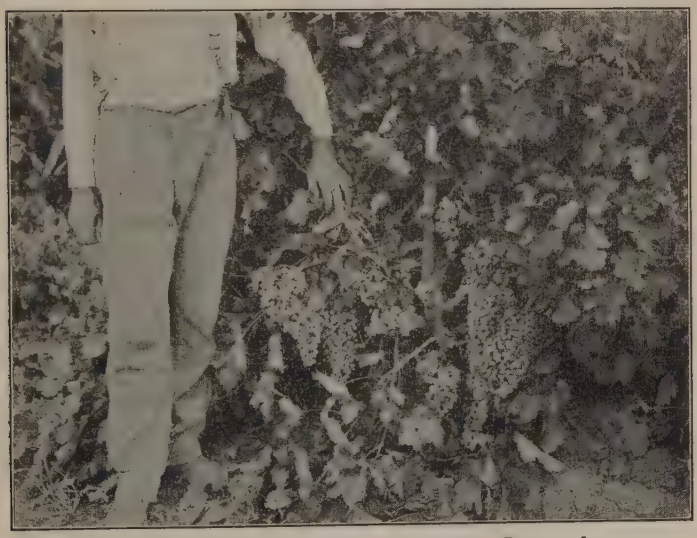


FIGURE 397. — GRAPES GROWN ON IRRIGATED DESERT LAND.

through canals and tunnels, and is distributed to crops as needed. In this way, nearly a million of acres have already been made fertile which before were unable to produce crops on account of the absence of rainfall.

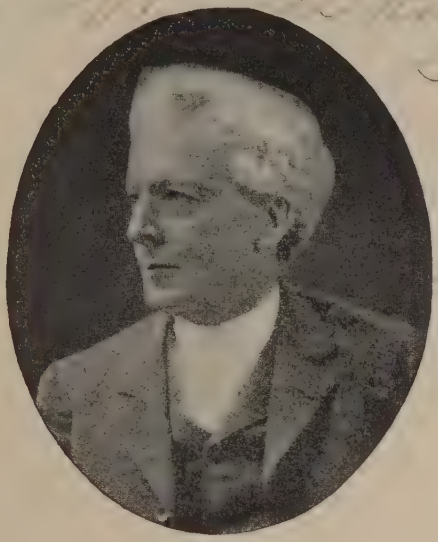
This work in the United States is carried on by the government under the name of *reclamation projects*. More than twenty such projects have been successfully carried out, and the land sold to settlers at reasonable rates. More than twenty thousand persons are now living in regions

formerly unfit for habitation. It is estimated that there are about thirty millions of acres that can be reclaimed by carrying on this work.

Any crop can be raised on irrigated land that the character of the soil and the climate make possible. All kinds of fruits are produced in abundance in some portions of the western irrigated lands, on others garden produce is raised, and on still others grains and hay.

FIGURE 398. — APRICOT TREE IN ARIZONA.

409. Rotation of Crops. — Since no two plants use exactly the same amounts of raw materials from the soil, or the same amounts of any one substance, farmers plant first one crop on a field and then another of a different kind. Instead of planting corn, for instance, year after year they vary it with some other crop. If a leguminous crop is planted every third or fourth year, nitrogen is restored by the bacteria



Luther Burbank (1849, still living). Burbank is noted for his skill in selecting the most promising young plants, one or two, out of hundreds, and carefully rearing them. He has made many experiments in plants, producing the thornless cactus, stoneless prunes, and numerous other valuable variations. He conducts the Burbank Experimental Farms at Santa Rosa, California. On this farm as many as 6000 experiments are under observation.

which are associated with the roots of these plants. (See page 594.)

410. Enemies of Plant Life. — The enemies of plant life are weeds, insects, and certain kinds of bacteria and fungi. (See page 575.)

Weeds are plants which interfere with the growth of some cultivated plant or crop. Common garden flowers, like the poppy and the pansy, sometimes become weeds. Weeds deprive other plants of light, moisture, and raw materials from the soil.

One of the purposes of cultivation of most crops is to keep the weeds under subjection. Incidentally the soil is loosened so that it can absorb and retain water more easily, and admit air to the roots of the plants. In fighting weeds a knowledge of their habits and of plant life in general enables one to keep them under control. In general, the best way to get rid of weeds is to keep them from reproducing.

Insects injure plants in several ways: (1) by eating the substance of the plant, especially the leaves and the roots; (2) by sucking the juices from the tender parts; (3) by carrying the spores of bacteria and fungi from diseased plants to healthy ones.

Bacteria and fungi are the cause of such diseases as smuts, rusts, rots, blights, and mildews. Some of these kill the plants outright, and others seriously reduce the yield of fruit or grain. (See page 580.)

OUTLINE

Relation of soil to plants
  Necessary
    For anchorage
    For nourishment
      Moisture
      Food

Kinds of soil
  Quality
    Alkaline
    Acid
  Texture
    Gravel

- Sand
- Loam
  - Humus
- Clay
- Muck

Preparation of soil
- Plowing
- Harrowing
- Raking
- Spading

Seed selection
- Dormancy
- Viability
- Testing

Methods of planting
- Hills
- Drills
- Furrows

Need of cultivation
- Objects
  - Loosen soil
  - Conserve moisture
  - Kill weeds
- Irrigation
- Transplanting

Soil exhaustion
- Nitrogen cycle
- Fertilizers

Irrigation and dry-farming

Rotation of crops

Enemies of plant life

SUMMARY

Plants get the raw materials for their food from the air and from the water which their roots absorb from the soil. Soil is of use to a plant in anchoring it, in retaining moisture, and in supplying part of the raw material it needs. Water is taken through the root hairs by osmosis. Loam is the best kind of soil to hold moisture and to furnish raw material.

Soil must be prepared for crops by plowing and other methods. The methods of planting crops vary according to the kind of crop and the use to be made of it. Crops must be cultivated to conserve moisture, make penetration by the roots easy, and to kill weeds. Desert lands can be made productive by irrigation.

Every plant that grows takes materials from the soil, which leave it poorer for the plants which grow later. Plants are the only organisms that can gather the nitrogen from the air and restore it to the soil. This is done either directly by bacteria, or indirectly by the death and decomposition of the plants themselves or of the animals which eat them. The wastes of live animals also help to restore nitrogen to the soil.

The enemies of plant life are weeds, bacteria, fungi, and insects.

QUESTIONS

Where do plants obtain the raw materials for making their food? In what ways is soil of use to a plant? Name the kinds of soil. Describe humus. Tell why it is valuable. What methods of planting are

used? Why are crops cultivated? What is irrigation? What is meant by dry farming? How do plants exhaust the soil? How can productiveness be restored? How can it be increased even on good soil? Describe the "nitrogen cycle." What are the enemies of plant life?

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Bergen and Davis, Principles of Botany, pages 500–513.
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PART V

GENERAL BIOLOGY

CHAPTER XXXV

APPLICATION OF BIOLOGICAL PRINCIPLES TO HUMAN INTERESTS

Take not away the life you cannot give
For all things have an equal right to live.
— DRYDEN

411. Interdependence and Interrelation of Living Things. — The organic world is so constituted that plants have come to depend on animal life for many of their needs. This has not always been true, for there was a time ages ago when the organic world was made up entirely of plants. As plants manufacture food out of the raw elements of nature, they are necessary before there can be any general development of animals.

The dependence of animals on plants for their foods has been emphasized over and over again in this course. They have never been able to live without plants. The very food of animals is the plant, directly as in the case of the deer, cow, sheep, or indirectly as in the case of the lion, tiger, and cat where these animals feed upon other animals that have built up their bodies by means of plants. For example, the cat eats mice, but the mice eat seeds, roots, and bark.

Man eats plants directly, such as cereals and bread, as well as fruit, while indirectly he uses them in the flesh, milk, or butter of animals that in turn build up their bodies

by eating plants. The woolen clothes of man come from animals, while his linen is of plant origin. He lives successfully because he has learned how to cultivate and use the products of the life about him.

These simple illustrations of the interdependence and interrelation of living things will suggest many others to you. This balance may be further illustrated in an aquarium or a terrarium.

412. Balanced Aquarium. — In an aquarium we may establish a small organic world of animals and plants if there

FIGURE 399. — A BALANCED AQUARIUM.
This is easily made of snails and plants.

is a proper selection of water plants and aquatic animals. The animals will receive oxygen from the water that has been enriched with oxygen by the plants in their starch-making; and, in turn, the plants will receive some of their carbon dioxide from the animals as they carry on respiration. Suppose in an aquarium our plant is a small water lily and our animal a goldfish, then the lily may furnish some of the food

for the goldfish and the growth of the plant will more than make good the loss. The oxygen cast off by this plant will furnish all of the oxygen the goldfish needs.

When we get just the right amount of plant life that will supply the needs of the fish and just the amount of animal life that will supply the needs of the plant, we have a *balanced aquarium.*

It is not easy to maintain a balanced aquarium because the germ life and fungi from the air, water, and larger animals and even the plants themselves will multiply rapidly in the favorable conditions of an aquarium. This leads to pollution of the water and the death of the fish and plants unless it is arrested by proper treatment.

A balanced aquarium need not be the same each time; it depends on which organisms you select. An easy combination is made of water plants and snails. Frequently the minute hydra is a suitable animal. In short, a balanced aquarium can be established whenever the conditions of nature are closely imitated.

413. Balanced Terrarium. — Balance in nature is very general. What has just been outlined for aquatic organisms is equally true of those that live on and in the soil. If you desire to make a balanced terrarium a lettuce plant and a garden slug may be selected. The slug will eat some parts of the leaves of the lettuce, but a strong lettuce plant will grow faster than a slug can eat it. The lettuce plant will cast off oxygen into the air to add to the amount already there and this the slug will use in respiration. The carbon dioxide cast off by the snail can be used by the lettuce in starch-making.

Other plants and animals may be used in place of the lettuce and the slug. When such selections are made and confined in a suitable case, we have a terrarium. If the collection of plants and animals is just right in size and number we have a balanced terrarium. Again the germs and fungi being always

present may attack the old or injured lettuce leaves or any waste matter in the terrarium and thus destroy the balance.

The balanced aquarium and terrarium are simply convenient ways of illustrating these important relations as they exist everywhere in nature. Those of you who can make your observations out of doors are fortunate. It is expected that you will be on the lookout for these relations wherever you are.

Longfellow wrote a poem as part of the celebration of the fiftieth birthday of Agassiz which expresses this attitude.

"And Nature, the dear old nurse, took
The child upon her knee
Saying 'Here is a story-book
Thy Father has written for thee.

"'Come wander with me,' she said,
'Into regions yet untrod;
And read what is still unread
In the manuscripts of God.'"

414. Animals as Friends and Enemies of Other Animals and Man. — Review the Insects and Birds especially in this connection. The Bees and Flowers are discussed on pages 98–104.

415. Earthworm and Plant Life. — Many years ago Darwin made a very thorough study of the importance of the earthworm to plant life. Ever since this time, the earthworm has been studied by all those who are in any way interested in the interrelations of organisms. If we are to gain any adequate idea of just how this relation is brought about, it is necessary to examine first of all the general structure of this simple organism and see how its digestive organs, especially, are adapted to securing their food from the soil.

The Body.—When one examines a living earthworm, the head end can be determined as the one which first moves forward. Actually there is no head; nor are there special

sense organs. The muscles in the front end are stronger and the body rounder than in the back end. The back, or *dorsal* (dôr's'l), part of the worm which is exposed to the light is darker in color than the rest. This surface is rounder than the opposite (under) one which is in constant touch with the dirt when the worm is crawling. The flat surface upon which the worm crawls is the *ventral* (vĕn'tral) surface.

The body of the earthworm is made up of a number of segments (rings) which are marked off by shallow grooves. Some of the segments in the front end are larger than those that make up the back end, but all are similar in shape.

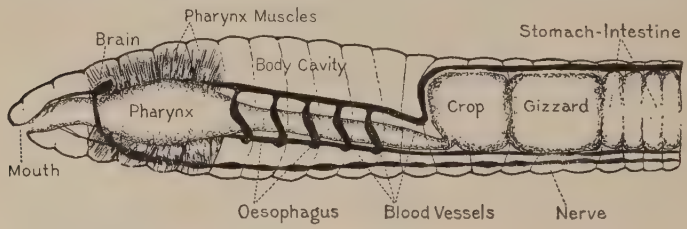


FIGURE 400. — DIAGRAM OF THE BODY OF AN EARTHWORM.

The number of segments depends mostly upon the age of the earthworm. It is from 60 to 150 in full-grown worms.

Life Processes. — While the earthworm has all the life processes common to living organisms, the only one we shall take up at present is food-taking, as that is the one most affecting human interests. The food of the earthworm is chiefly the soil in which it burrows. By means of an upper lip, which is a specialized anterior segment, and the muscular walls of the pharynx, it takes the earth into its body, and the muscles of the digestive tube advance the food along its course. The soluble and therefore digestible parts are absorbed, and the remainder (the greater portion) is passed along to the outside. Earthworms are not critical in the selection of their food, although they are not entirely without a sense of taste.

Economic Importance. — After a rain you have often noticed the large number of earthworms crawling on the sidewalk or pavement, if you live in small towns or in the suburbs of a city; or if you chance to be so fortunate as to have a garden spot, you have noticed their openings and castings when you examined your garden in the early morning. These observations give you some idea of how numerous earthworms are in fertile soil.

Darwin estimated from painstaking observations that in some of the meadows of England the earthworms brought up from the lower layers of the soil from ten to fourteen tons per acre. After this large amount of soil has passed through their digestive tracts and been deposited on the ground plant roots have easy access to it, and are thus supplied with soil that contains important substances out of which they manufacture their own food. You have already learned that plants exhaust the soil and that it has to be artificially enriched, but for hundreds of years earthworms have been slowly making the soil more favorable for plant life.

As earthworms burrow their way through the soil, they leave passages for the water and air to enter, thus again assisting plants to grow. The constant plowing of the soil, as Darwin termed it, by earthworms has also been an important factor in leveling inequalities, and thus has been a factor in adding to the attractiveness and beauty of the land.

416. Cellular Structure of Living Things. — Throughout this course the same term, the *cell*, has been found satisfactory in describing the minute structure of every living thing. We have seen that the root, stem, and leaf of the plant are made up of cells. This is true of every plant that you have studied, whether large and complex like a pine tree or simple like the fungi. Likewise the tissues and organs found in animals are composed of cells. In the Protozoa the whole life is carried on within a body composed of but a single

cell. The human body with its organs and tissues is a grouping of cells.

In structure you have noticed that all cells are much alike. They vary in shape and size, giving rise to different kinds of tissues and organs. The work which goes on in the living protoplasm of one cell is much alike in all. Plant cells contain cellulose in their cell walls. This forms the chief distinction between an animal and a plant cell, for this carbohydrate is not present in animal cells. In some of the very simplest organisms, it is difficult to be certain whether they are plant or animal, but in the great majority of plant cells cellulose is present.

417. Protoplasm and the Cell. — The active living part of all cells is the protoplasm. This is the part that grows, moves, and makes the organism alive. In a green plant that looks fresh and strong, it is the protoplasm that gives it that appearance. When a kitten runs and jumps, it is the protoplasm of the cells that is active in reality. When a boy or girl skates or swims, we know that good healthy protoplasm of the cells is at the bottom of such movements. So far as we can tell all protoplasm is much the same thing structurally and reacts in much the same way whether it is in the plant, kitten, or boy.

When a plant grows, it is adding more cells; when the kitten grows, it is adding more cells; and the man is the boy with more cells added and more training and adaptations acquired. Nowhere in the animal or plant kingdom can we get away from the fact that the foundation of all organic structure is the cell with its living protoplasm. As a brick is a unit in a great building, so each cell is a unit in the huge tree by the roadside, the elephant in the zoölogical garden, or in a man. As living things grow older certain cells become less active, until in old age the tissues have ceased to grow. Finally, death is due to the failure of certain cells to do their part as they have been doing. This is the reason that the

expression " We are as old as our cells " is frequently used. It means that we are healthy when our cells, all of them, are doing their normal, regular work. Healthy cells make a healthy body.

418. Life Functions. — The principal functions of all organisms, animals, man, and plants, are sensation, motion, respiration, food-taking, digestion, absorption, circulation, assimilation, excretion, and reproduction. These have all been fully explained as you have studied animals, plants, and man. They should be reviewed again for the sake of comparison, and for this reason only a brief summary of each is here given.

(*a*) *Sensation.* — We all know that we have five sense organs, and students of physiology tell us that we have many more, but no matter how many there are, all require special cells to respond to the various stimuli such as light, sound waves, heat, cold, sour taste, etc. Such cells bring man in contact with his environment and help him to understand it. The brain of man is more highly specialized than that of any other animal, and his sense organs, taken as a whole, are better developed than those of any other living thing.

Most animals have sense organs, though they are simpler than those of man. But even animals without sense organs or a definite nervous system respond to heat and cold, light and dark because of the general sensitiveness or irritability of their protoplasm. Plants without nerves show many responses to light and dark, heat and cold.

(*b*) *Motion.* — The movement in living things which you have observed is unlike the motion of water or wind. The power for motion in organisms comes from energy stored within their own bodies. Animals are more active than plants and consequently utilize more energy. They change more potential energy to kinetic energy than do plants.

The simplest organisms move only a little, but higher organisms, especially man, are capable of remarkably varied

motion. The greater the complexity of structure, the more diversified the movements and the greater the division of labor among the parts.

(*c*) *Respiration.* — Oxygen furnishes a necessary amount of energy to all organisms. The simplest animals absorb it; others have more complicated adaptations for respiration. Animals that live on land have special organs, the lungs, that are adapted to taking oxygen from the air; while aquatic animals, like fish and crayfish, have gills that are adapted to taking oxygen from the water. The thin skin covering the body of the earthworm acts like a lung in that oxygen passes through it and into the blood. Plants have their leaves modified by stomata, and through these oxygen passes into the plant. Under some conditions the stems of plants take up oxygen. Aquatic animals and plants take up their oxygen through their cell walls.

(*d*) *Food-taking.* — Animals require food that has been built up into proteins, fats, or carbohydrates. In the protozoan this food enters the food-vacuoles, and in the higher animals and man it is taken into the digestive canal. Plants require food just the same as animals. They simply need less. There is apt to be some confusion in comparing plants and animals in regard to food-taking. All green plants manufacture food, which is either utilized by the plant or stored in root, stem, leaf, or seeds. Such stored food is eaten by animals. The fundamental need for food is the same in plants and animals. The plant has first to manufacture food before it can be utilized. Of all animals, man uses the greatest variety of food.

(*e*) *Digestion.* — The food in the stomach of animals and man is acted upon by an enzyme secreted by living cells lining the digestive cavity. Different enzymes grown in the pancreas produce further changes in the food after it reaches the intestine. The action of the several digestive enzymes is to reduce the foods to solution, which is digestion.

The parts of the food that are thus digested pass by osmosis into the blood. The same principles apply to the digestion of the food in the food-vacuole of a paramecium. The stored foods in a plant also must be digested before the plant can absorb them. Digestion, then, the reducing of foods to solution, is the same process in all organisms.

(*f*) *Absorption.* — This is the taking of the foods in solution into the blood of animals or into the veins of plants. After it has entered the blood or sap it can be carried to all parts of the body of the animal or plant.

(*g*) *Circulation.* — The carrying of food in solution to all of the *cells* of an organism is circulation. Such foods circulate through the cytoplasm of paramecia, for example, through the blood of animals and through the sap of plants.

(*h*) *Assimilation.* — Every cell in an organism must take the food that it needs from the blood or sap and build it into living protoplasm. This is assimilation.

(*i*) *Excretion.* — The energy used by organisms in their several activities results in the formation of various wastes. These wastes usually take the form of a gas, carbon dioxide, given off in respiration by animals and plants, or a liquid when discharged from the sweat glands or kidneys. The simple contractile vacuole in the paramecium assists in removing wastes, while the earthworm possesses numerous simple excretory tubes (nephridia) that take the place of kidneys in higher animals.

(*j*) *Reproduction.* — The unicellular plants and animals reproduce in a very simple manner by fission (division). In multicellular organisms reproduction begins in a single cell, the germ cell. This germ cell has the power to carry on a program of development that varies but little for all eggs of one kind. The fish egg and the frog egg look much alike, but each follows its own individual order of development until the adult stage is reached. There is no mistake, and the development is never interrupted in normal growth. There

can be no pause without disaster to the life of the forming organism. An egg may be kept before starting to hatch as we do with hen's eggs, but once started it must continue. The egg cell of plants and animals must be fertilized. This process is accomplished through the union of the male germ cell with the egg germ cell.

In all of your study about reproduction in plants, animals, and man, you must remember that a new organism can come into being only from living germ cells. You cannot cut off a leg from the frog and grow a new frog from it, nor can you cut any of the higher animals in two and have each part live. This important fact should help you to correct the common misapprehension that worms can be grown from horse hair or that frogs rain down.

419. Division of Labor. — Nearly all of the organisms that you have studied were composed of many parts, each of which did a particular thing that was important to the life of the organism. (Stem, leaf, root with all of their special tissues, each had its special function to perform.) The skeleton, nervous system, and digestive organs of the frog or man had also a particular work to do. In contrast to this division of labor in structures of greater complexity stand the more simple organisms of plant and animal life, for example, fungi and bacteria, and the unicellular paramecium. Here although all the life processes are carried on, they are performed by the whole organism.

In some organisms, the cells are alike in form and function, but in others, we find that a few cells have been changed in shape in order to perform better the special work of reproduction. This change is the first step in the division of labor.

This is well shown in the higher animals, where certain cells are grouped together for a given work. The digestive system contains cells which work to make solutions of the food eaten. These solutions nourish the whole body, not the cells of the digestive tract alone. Certain other cells

are modified in such a way for secreting and holding lime that they form bones by which the whole body is benefited.

Some cells are grouped to form muscles to be used in securing food and in enabling animals to escape from their enemies. Other cells are for the purpose of conveying and interpreting impressions, so that the animal may hear the approach of an enemy, or detect the presence of food. It is largely the carrying out of this "division of labor" that tells us the rank of an animal or a plant in biological classification.

In the business world we have a somewhat similar division of labor. Years ago the cobbler made all the parts of a shoe. In our large shoe factories to-day we find no one man making an entire shoe. One man runs the machine that cuts the leather and he does no other part of the work. He may have been a cutter twenty years, and he works rapidly and accurately. Another man runs the machine which sews uppers to the soles. He, too, is a rapid and skillful worker. Other men have their special lines of work to do. In the end they produce more shoes and better shoes than this same number of men could if they were all cobblers and each finished his product.

Division of labor increases the more complex the structure becomes. This fact can be illustrated by studying several organisms of increasing complexity, gonium, volvox, sponges, and hydra. This idea of division of labor in organisms can be shown just as well from plants as from animals, and those teachers who do not wish to use the sponge and hydra will find that marchantia, mosses, and ferns show the gradual formation of root, stem, and leaves as well as the differentiation of tissues and reproductive organs.

420. Gonium. — Gonium is an animal made up of sixteen separate cells held together by a mucilage-like secretion of the cells. Each cell works independently in getting food, respiring, giving off waste, and in reproduction. The colony moves

by lashing the water with long protoplasmic threads (flagella), two of which project from each cell. The advantage in rate of movement resulting from the union of cells is illustrated in rowing. Eight men in a large rowing shell can go faster than one man in a single, small shell. In reproduction, the sixteen cells fall apart, and each one grows into a new colony.

FIGURE 401. — GONIUM.

421. Volvox. — *Volvox* is a colony of hundreds of tiny green cells embedded in a hollow gelatinous sphere. Each cell has two flagella. For a time all the cells are alike and share equally in the work of the colony. But in reproduction only a few cells take part. In the simplest method, a few cells grow large and escape into the hollow sphere. There, they divide and grow into new colonies. Finally, the mother colony breaks, and the daughter colonies escape.

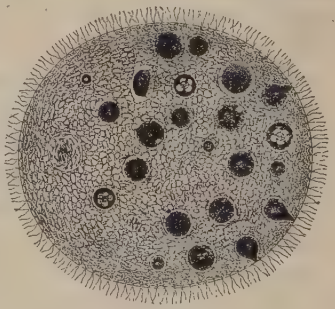


FIGURE 402. — VOLVOX.

The more complex method is like the reproduction of higher animals. Certain cells in the colony grow large and escape into the hollow sphere. They are the *egg cells*. Other cells of the colony enlarge and divide into large numbers of slender, free-swimming cells called *sperm cells*. The sperm cells escape into the hollow sphere and swim about. One sperm enters an egg cell and unites with it, forming a single cell, the *fertilized egg cell*, which can develop a new colony.

422. Sponges. — Sponges are simple animals composed of many cells. In them we find division of labor carried out in a more complex way than in gonium and volvox. Simple sponges have a body in the form of a hollow cylinder. Water enters through the sides of the body and passes out through a hole in the top. A simple sponge, called *Grantia*, grows in salt water attached to docks or other objects submerged along the seashore. On examination, it is observed that grantia is less simple than volvox.

FIGURE 403. — A SIMPLE SPONGE.

Structure. — Grantia is composed of three layers of cells which show division of labor. The inner layer is called the *endoderm* (en′dō-derm). It consists of cells provided with flagella which, by their movement, produce a current of water through the central cavity. The water enters through the holes in the sides (inhalent pores) and is forced out through the opening at the top pore (exhalent pore). The water contains food particles which the cells of the endoderm have the power to take in and digest. The food solution is passed to the other cells in the sponge body by the process of *osmosis*. This is a process in which gases or liquids of unequal densities, separated by a plant or animal membrane, tend to mix and become alike.

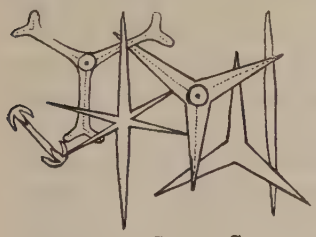


FIGURE 404. — SPONGE SPICULES.

Thus the food digested is passed on and nourishes the cells of the middle and outer layers. The cells of the middle region form *spicules* (spĭc′ūls) of lime (Figure 404) that project through the other layers and strengthen the whole body. The outer layer or *ectoderm* (ek′tō-derm) serves as a protective layer and with the help of the spicules gives definite shape to the body.

FIGURE 405. — A BRANCHING SPONGE.

Reproduction. — At certain times of the year the sponge reproduces by means of two kinds of cells (eggs and sperms) developed in the middle layer. A sponge may develop both eggs and sperms, but usually develops only one kind at a time. Cells from the middle layer move in between cells of the endoderm and grow large and round. These are the eggs (female cells). Other cells move into the endoderm layer and divide into many small ciliated cells (the sperm or male cells). The sperms are set free and escape into the water of the central cavity and out from the body of the parent sponge. A sperm enters the body of another sponge and when it finds an egg, fuses with it, thus forming the fertilized egg. The fertilized egg then begins to grow, and after a definite period breaks away from the parent, moves about for a time, and then settles down, attaches itself, and grows into a mature sponge. The immature sponge has the

power of locomotion, but the mature form has lost this power. Nevertheless the sponge is an animal.

Reproduction that comes about through the fusion of an egg and a sperm is called *sexual reproduction*. The other method of reproduction, called *asexual reproduction*, also occurs among sponges. By this method, sponges form little buds or branches which develop into new sponges.

423. Hydra. — The *hydra* is an interesting fresh-water animal about a quarter of an inch in length which carries the division of labor a step farther. Its body is shaped like a little cylindrical bag with only one opening, the mouth, which is surrounded by a few, usually six, delicate, thread-like arms called *tentacles* (tĕn'ta-kls). The body is composed of three layers, the outer layer, *ectoderm;* the middle layer, the *mesoglea* (mĕs-ō-glē'a: Greek, *mesos*, middle; *gloios*, glutinous substance); and the inner layer, *endoderm*.

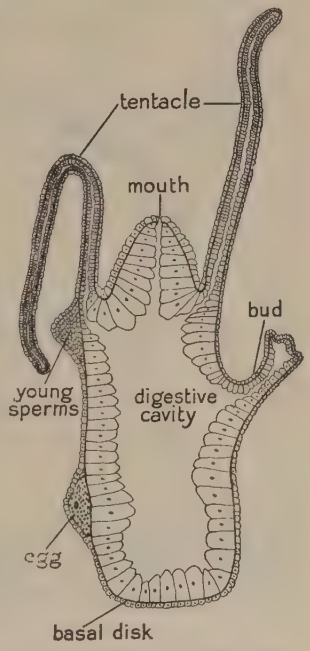


FIGURE 406. — DIAGRAM OF BODY OF HYDRA.

Each layer does some particular work for which the others are not fitted. For example, the outer layer contains cells which are especially sensitive to stimuli and many modified muscle cells that enable the animal to move about. The inner layer contains cells provided with flagella which catch the food particles for the inner cells to digest. The muscular action of the outer layer moves the entire animal. The sensitive cells enable the animal to recognize its prey. The food

digested by the inner layer is used by all the cells of the body. Thus we see an advance in the division of labor over that shown in the sponge. We shall observe a still greater increase in division of labor as we study higher animals.

Tentacles are hollow, finger-like branches connected with the body cavity. They are provided with stinging cells which help the hydra to capture living water fleas and the like. These stinging cells have darts which are automatically discharged when the tentacles come in contact with little animals. The darts poison the prey and render escape impossible. The tentacles surround the food and carry it to the mouth, which opens directly into the food cavity.

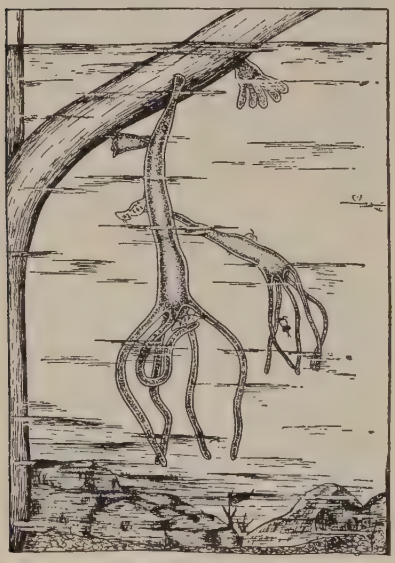


FIGURE 407. — HYDRA.

The united cells in the hydra are connected with one another through the cell walls. In the higher animals we shall find that connections between cells are made by means of nerve cells. The development of a nervous system only carries out division of labor to a greater degree.

Locomotion. — The adult hydra is usually found attached as in Figure 407. In this condition the only movements possible are such as take place in the expansion and contraction of the whole body. The tentacles wave about in the water, and as the hydra expands, the body may move first in one direction, then in another. In this sense the

hydra does not move about as does a grasshopper or a paramecium. At infrequent intervals, however, the hydra detaches itself and moves from place to place by attaching the tentacles, then the base, then the tentacles, much like a boy turning handsprings.

Nutrition. — The hydra feeds almost entirely upon minute animals. The forms that furnish the greater amount of their food are shown in Figure 407. These animals belong to a much higher group of animals than the hydra; namely, the Crustacea, the group to which the crayfish and crabs belong. These animals which have an exoskeleton like insects are rendered inactive by the stinging cells on the tentacles. The paralyzed animal is then brought to the mouth by the tentacles, Figure 406, and swallowed. Within the body, the nutritive parts are digested by enzymes as in other animals and absorbed, passing by osmosis to all the cells. The indigestible skeleton of the animals eaten is cast out through the mouth.

Respiration and Excretion. — By osmosis, oxygen is absorbed from the water by the cells of the ectoderm. The water that enters the mouth carries oxygen, and by osmosis it is absorbed by the cells of the endoderm. At the same time the carbon dioxide from the cells is thrown off into the water.

Irritability. — The hydra is able to appreciate a variety of different kinds of stimuli such as jars, a moving animal, or an enemy. It is able to contract, expand, and move the tentacles in such a way as to bring food to the mouth, although it does not possess nerves or a brain. When a special study of the structure of the hydra is made, nerve cells are found which assist it in responding to stimuli. In the Protozoa there are no special nerve cells, but the hydra shows the beginning of the formation of a nervous system.

Reproduction. — The hydra reproduces both sexually and asexually. In sexual reproduction eggs and sperms are

produced by the ectoderm cells. The sperm cells escape into the water and, like sperm cells of all other animals, have the power of locomotion. The fusion of the egg cell and a sperm cell starts growth, which results in the division of the egg cell into many other cells. Hydras also reproduce asexually by budding. The buds soon separate from the parent and begin an independent life. Like the developing sponge, the developing hydra grows until it finally becomes a fully formed hydra.

As the layers in the body of the hydra become more distinct, the division of labor is more marked.

From the simple layers of tissue, we pass to the formation of organs, for which the earthworm previously described is a good illustration. The earthworm is much simpler than a crayfish, but in turn the crayfish does not have a well-developed head such as the fish or frog. Thus you can trace a greater division of labor with the complexity of structure as you pass from the simpler to the higher animals.

424. Oxygen, Carbon, and Nitrogen Cycles. — In our study of the apple tree, we learned that eventually the tree grew old, decay set in, and the rotting stump was all that was left. After a while even this stump disappeared and the entire tree had vanished. The same set of events occurs in the life of all organisms. Energy in the form of food and oxygen (which is in the form of a compound) is taken up and becomes a part of the bodies either temporarily or for some considerable time.

Life has thus been utilizing energy since it first began, and it will continue to do this as long as there is life. At first thought, one might say that there must come a time when some at least of the necessary substances will become exhausted and life will have to cease. This used to be believed, but ever since men have known about the work of microorganisms and the manner in which oxygen is used, the theory that life will have to stop because of the lack of some of the needed compounds has been denied.

Oxygen. — We shall first review the cycle of oxygen. This important compound is taken into the body and takes part in oxidation. There results a waste product, carbon dioxide. Carbon dioxide is taken up by the green plant and the carbon becomes a part of the starch, while the oxygen is set free and escapes into the air ready to be used again by some organism in respiration. Oxygen can go through this series of changes an endless number of times without losing any of its properties. It is thus said to go in a cycle or circle in its relation to living things.

Carbon. — The carbon which is a part of starch remains in this food until some organism utilizes it. The organism may set it free as a waste product in carbon dioxide, to be later built up into starch in photosynthesis. The scientists who have tried to discover just which elements are in living protoplasm all agree that carbon is present in large amounts. It constitutes about 72 per cent of our own bodies. The carbon that is a part of the living protoplasm remains in this relation for an indefinite length of time, being finally released when the protoplasm dies. In this way it differs from oxygen. There is thus a carbon cycle just as there is an oxygen cycle.

Nitrogen. — Nitrogen is another important element found whenever organic matter is analyzed. Living things cannot utilize nitrogen unless it is in a complex form. Animals require proteins which are very complex. These proteins in turn are manufactured by green plants. When an organism dies the nitrogen compounds are made simpler by the action of bacteria (page 390). Green plants take up nitrates (simple nitrogen compounds) and store the nitrogen away in proteins. Undoubtedly many of the compounds built up by the animal and plant would automatically break down after death, yet bacteria hasten the process as they feed on them. In this process of decay, the compounds are almost completely broken down and the result is that the nitrogen

has now become so simple (simpler than nitrates) that green plants cannot utilize it.

The group of bacteria (denitrifying bacteria) whose activities are spent in changing nitrates into gaseous nitrogen allow the nitrogen to escape into the air, thus putting it beyond the reach of green plants. Then there come the nitrogen-fixing bacteria, which rescue this gaseous nitrogen from the air and unite it with other elements suitable for green plants to use.

The nitrogen cycle is thus very complex in comparison with the oxygen cycle, and it is no wonder that the complete story remained untold for many years. Scientists had to learn a great deal about the life of bacteria before they understood how important a part they play in the life of all of the higher organisms, including man.

OUTLINE

- Interdependence of living things
  - Plants on animals
  - Animals on plants
  - Illustrations
    - Balanced aquarium
    - Balanced terrarium
- Animals as friends and enemies
  - Earthworm
    - Life processes
    - Economic importance
- Cell structure
  - Protoplasm
- Life functions
  - Sensation
  - Motion
  - Respiration
  - Food-taking
  - Digestion
  - Absorption
  - Circulation
  - Assimilation
  - Excretion
  - Reproduction
- Division of Labor
- Gonium
- Volvox
- Sponges
  - Structure
  - Reproduction
- Hydra
  - Life processes
- Cycles
  - Oxygen
  - Carbon
  - Nitrogen

SUMMARY

Animals, plants, and man live in close relation to one another. Both man and animals are dependent on the work of the green plants. There is a constant struggle going on in nature between the several kinds of

organisms that try to live in any given pond or on any bit of land. While they struggle for a place to live and food to eat, they in turn contribute necessary substances to one another. Even the insignificant earthworm has been an important organism in increasing the productivity of the soil. The protoplasm of all forms of life is similar and confined in similar cells. Within these cells takes place all of the activity of organisms which we know as life functions. In order that these life functions may be carried on better, a marked division of labor is evident as we pass from the lower to the higher organisms. Organisms utilize energy in living but there is no danger that the supply will ever become exhausted, because it has been shown that the elements of which the compounds yielding energy are composed pass in a cycle assisted by the work of microörganisms, and without which the various cycles would be impossible.

QUESTIONS

Explain how organisms are dependent on one another. How are they beneficial? How harmful? What is a balanced aquarium? A balanced terrarium? Do you think that these conditions exist in nature? How does the earthworm help plant life? Is its digestive system adapted to this work? Explain. Just how do bees help flowers? How do some insects injure plants? Define a cell. What is the difference between a plant cell and an animal cell? Name the life functions of organisms. Do these apply to man? Which organisms help you to understand how the plan of division of labor began? Is it a good thing? Illustrate in animals and plants. Explain the carbon cycle. The nitrogen cycle.

CHAPTER XXXVI

HEALTH AND CONSERVATION

Nor love, nor honor, wealth nor power
Can give the heart a cheerful hour
When health is lost. Be timely wise;
With health all taste of pleasure flies.

— Gay

The progress of science has indicated very clearly that there is an unnecessary waste of human life, and our course of study has revealed something of the devastation that comes from communicable diseases — all of which are preventable. A similar destruction and prodigal waste has taken place in our biological resources.

Several agencies have been set up which aim to substitute prevention and conservation for this loss. A study of health agencies and conservation of biological resources are taken up in this chapter.

425. Health Activities. — In our study of bacteria, we came to realize that these minute organisms are the cause of many communicable diseases, and, when we review the relation of the protozoa to our welfare, we realize that these two classes of germs are the main source of disease. If we are to keep ourselves well and help to prevent these diseases, we must observe the laws of hygiene and quarantine.

So few people have realized the importance of the facts which you have been studying that laws have been passed regulating our activities. It is important that you should first understand what health agencies exist in your municipality and then give your support to them. But local health regulations are often inadequate to govern a situation, and

the entire state or nation must assume control. For this reason we have state and national health laws.

Special foundations have been instituted by private individuals who have given large sums of money to further the work of scientists in the study of the causes and prevention of disease. The results of any discoveries are given to the public, where they may be of immediate benefit to the people. What are some of these important health agencies?

426. Municipal Health Agencies. — The civic authorities of towns, villages, and cities are charged with the duties of administering the laws and caring for the well-being of the people. A certain amount of the taxes are set apart by the civic authorities to care for the health of the people.

Our streets and parks are improved at great cost. These have to be protected and repaired. The care of the streets is usually under a separate department whose business it is to see that they are cleaned and flushed and to remove dirt and decaying matter, which are a source of danger to health.

Public health activities usually center in a public health officer who is charged with enforcing health regulations, supervising school hygiene and quarantine. The laws which govern these several activities are made in most instances both by the state and by the municipality.

In a large number of the cities and counties of New York State there are public health laboratories. In order that you may have some idea of the kind of work that goes on in such laboratories, the following summary is given. In the annual report of one city of New York State 10,872 diphtheria cultures were made; 399 examinations of blood and 1,293 cultures of sputum of patients suspected of having tuberculosis; 3,073 chemical and bacteriological analyses were made of milk and 213 of cream. The drinking water of this city received repeated study, as the 630 tests for *Bacilli coli* indicate. There were 176 inoculations for ty-

phoid and 973 miscellaneous studies. This does not include the work done by the public health division, which has charge of vaccination against smallpox. Not only were the dairies near the city inspected, but more distant dairies were regularly examined.

427. Pure Water Supply. — Plenty of pure water for drinking and cooking is indispensable to man. The neces-

FIGURE 408. — ONE OF NEW YORK CITY'S RESERVOIRS.

sity for disposing of sewage has made this problem increasingly difficult. Sewage-polluted water is never entirely safe for drinking. The two must be kept separate. This is the main reason why so much money has to be spent to bring drinking water to our cities, and this is the reason why so much care is taken to prevent this same drinking water from becoming contaminated. Some of the smaller towns have not yet come to appreciate the value and importance of having pure water to drink. The result is frequent epidemics of sickness.

In Figure 408 is shown a model reservoir. It is well located and all possible sources of surface drainage have been eliminated. In Figure 409 is shown a reservoir in which the conditions are the reverse. The water is stored in a place surrounded by residences and swampy ground on the left of the photograph. The open channels in the grass are

FIGURE 409. — A POOR RESERVOIR.

Note the open stream that empties into the main body of water. The impure water of the Erie Canal drains into this open stream.

streams that empty into the water of the reservoir. One of these is supplied from the overflow of water of the Erie Canal. This alone is sufficient explanation of why there have been frequent epidemics in the town that has this water supply. What are the conditions surrounding the water supply of your home?

Cities and villages need more water than old-fashioned

wells can furnish. To secure this increased supply, lakes, rivers, or a group of wells are drawn upon. When a supply of water is brought to a village or city from lakes or rivers, the health authorities pay particular attention to the purity of the water. If it is likely to be polluted, certain germicides are forced into the water to destroy disease germs. If it is too hard, that is, contains too much lime, it may be softened by adding materials which precipitate the lime. If it is deficient in iodides (iodine compounds) it will tend to produce goiter among those who drink it. Iodides may be added in small amounts so that no danger from goiter remains.

Regulations are enforced by proper officials so that the water may not be polluted at its source. Some large cities buy the land adjoining the lakes and reservoirs and remove all cottages and residences as a means of preventing contamination of the water.

428. Proper Sewage. — In every town and city where a general water supply is established, it is necessary to provide means for the removal of the waste water. This water comes from homes, places of business, and various manufactories. Not only the wastes from the human body but also from the street washing, the waste products of various factories, and the annual rainfall and snow are all added to the waste waters of a city or town. Such water is known as sewage.

It is now known that there is an average of one hundred gallons of sewage daily for every inhabitant of a city. The daily sewage from homes averages about thirty gallons for each member of a family; but when we add the street flushing and wastes of various manufactories the total amount per capita is not far from the larger amount named. Thus in a city of 100,000 inhabitants, there will be about ten million gallons of sewage a day. What must be the daily average of sewage in your city?

Disposal of Sewage. — The question of what shall be done with all this vast amount of sewage is one of the most diffi-

W. T. Sedgwick (1855–1921), a member of the Department of Biology and Public Health at the Massachusetts Institute of Technology for thirty-eight years, devoted his training and energy largely to making cities healthful. He was one of the foremost American biologists in making investigations upon milk, water, sewage, and epidemics of typhoid fever, and in showing how to apply these technical studies to human welfare.

He was one of the first to study the bacteria of the air, and his work on the "Principles of Sanitary Science and Public Health" (1902) was an important contribution to public health education. In addition to this marked service to his countrymen, he devoted his life to teaching biology and sanitary science and to training biologists and public health workers.

One renders a great service to his age who leaves the world safer to live in than he found it.

cult that cities are trying to solve. The cities that are located on or near the ocean or Great Lakes let their sewage run into them. Those that are built on a stream or river empty into this small body of water and the town or city farther down the stream does the same. Where does the sewage of your city or town go?

Stream Purification. — Some recent studies made under the direction of the Massachusetts Institute of Technology show that there are a number of biological factors that assist in the purification of sewage-polluted water. These are a number of organisms that feed upon the organic matter that is suspended in the water. The first living things to be found where the water is most polluted are bacteria. As the sewage empties into the stream it is rich in food for bacteria and they become very numerous. As they feed upon this food, it is broken up into simpler chemical bodies and the water becomes clearer. A little farther away from the mouth of the sewer are found numerous protozoa that feed upon these bacteria and thus tend to remove them from the water; while still farther down the stream are to be found numerous tube-bearing worms that in turn feed upon the protozoa. If the water is now examined, it is found to be much clearer, for most of the sediment has either settled to the bottom or been destroyed by these several organisms. Nevertheless such water as this is not fit to drink.

Septic Tanks. — We take our drinking water from lakes and rivers, but strangely enough we pour our sewage into these same bodies of water. Large septic tanks are employed in some cities and villages, where all the sewage is allowed to ferment, with the result that disease germs are destroyed. The outlet from these tanks takes away the liquid part and pours it into lakes and rivers with practically no danger to public health. The solid portions from the tanks makes good fertilizer for depleted soils. In time we shall come to prize our public health so much that we will not allow any

sewage to pollute our rivers or lakes. This will come only with a keener sense of responsibility among all people for the preservation and conservation of health.

429. Supervision of the Milk Supply. — Intimately connected with our water supply is our milk. If milk cans and milk bottles are washed in impure or polluted water, each can or bottle is likely to hold some of the disease germs. When milk is placed in these containers the germs multiply rapidly, especially if the milk is warm, because the milk furnishes food for these bacteria which grow best in a warm temperature. Under such conditions the milk soon becomes a menace to the health of all of those who use it. A pure water supply is a good start towards a clean milk supply.

If milk is produced by dirty or diseased cows or handled by dirty or diseased people, it will contain disease germs and become a menace to health. For these reasons public health authorities examine and test milk containers and the cow stables, as well as the health of the cows and the health of the men who handle the milk. Sometimes, through carelessness or accident, milk may be contaminated and not be detected by the inspectors of the health department. If all the milk is treated as if it were contaminated, by heating to a temperature a little below the boiling point for a half hour, practically all disease germs are destroyed and the food value of the milk remains unchanged. This treatment is *pasteurization.* It is recommended for all milk, the purity of which is in doubt.

430. Care of Other Foods. — The care of food is extremely necessary in preserving our bodily well-being, for the same germs which cause disease when taken into the body live and grow on food. Fruit and candy exposed to dirt and dust or to flies are a menace to health. Such fruits as strawberries, blackberries, peaches, figs, or dates should be kept covered; and candy should be protected by cases or boxes. More and more health regulations are being formulated to

protect our food as it is being transported from the place of production to the consumer. We used to see the meat companies transporting carcasses uncovered through our streets, and in many places protection is still inadequate.

It is not fair to lay all of the responsibility upon those who handle our food before it comes to our homes. The same hygienic precautions must be taken by us. One method of keeping the bacteria on food from growing is by proper refrigeration. The temperature of a well-cooled refrigerator does not destroy the germs, but makes them incapable of growth. If food is taken from the refrigerator and allowed to stand for a time, the bacteria will at once begin to grow and cause the food to spoil. If such food is eaten an intestinal disturbance usually results.

431. Municipal Quarantine. — Our public health officials must not only supervise the several activities which have just been described, but it is their duty to see that the quarantine laws are obeyed. Certain diseases like measles, whooping cough, diphtheria, and scarlet fever are contagious. Persons who have such diseases may communicate them to healthy people by transferring the germs from their bodies. To prevent the spread of these diseases quarantine regulations are established so that healthy people are not brought in contact with those who are sick. Patients may be quarantined in one room of the house.

Nurses and physicians who are careful attend patients who have these diseases and do not contract them, nor do they carry them to other healthy people. The chief danger comes from those who are inexperienced and from those who do not understand how contagious diseases are spread. This is so important that we restate that the germs must be conveyed from the patient to the healthy person. This may be done through the air, which becomes infected from the discharges from the patient's nose or mouth when he sneezes or coughs. Contagion may come through soiled linen, such as

handkerchiefs or towels that have been used by the patient; or it may be conveyed by kissing or handling a patient. Nurses who care for persons suffering with a contagious disease are very careful to wash their hands in an antiseptic solution in order that they may kill all germs that are on them.

432. General State Supervision. — Each state maintains a health department which administers health laws affecting the whole state. In some states this has become an institution of far-reaching importance as measured by the decrease in death rates over the whole state. When a village or a city is temporarily afflicted with an epidemic the specialists and nurses from the state health department cooperate with the local authorities.

In addition to this valuable work many state health departments produce serums and vaccines for the use of citizens. These serums and vaccines are used successfully to combat diphtheria and to prevent typhoid fever. They are difficult to produce and are correspondingly expensive.

New York State Department of Health. — This department has been subdivided into proper separate bureaus. These divisions are: Sanitation, Laboratories and Research, Vital Statistics, Communicable Diseases, Maternity, Infancy, and Child Hygiene, Public Health Education, Tuberculosis, Venereal Diseases, and Public Health Nursing. The popular results of these divisions are published in a weekly bulletin called the *Health News*, which you should have in your school library and should read.

433. The Hygiene of Country Schools.[1] There are about 186,000 one-teacher rural schools in this country, and the children attending them constitute more than 50 per cent of all school children in the United States. The sanitary and hygienic conditions of these schools, therefore, constitute an important public health problem to the community.

[1] This section is taken from Clark's *Hygeia*.

Health supervision of school children first started in this country about thirty years ago, and since that time considerable advance has been made. Unfortunately, however, progress has been largely confined to the cities, while in many of the rural schools deplorable conditions still exist. The buildings are old and in a bad state of repair, the classroom illumination is faulty, the ventilation inadequate, and some of the schoolhouses have served their present purpose for three generations. The children who attend them are largely denied the medical and surgical attention by specialists so often given to city school children. They do not receive the benefits of general sanitary measures such as a good common water supply and the safe disposal of human excreta, and they are unduly exposed to diseases such as malaria and hookworm.

The evil results of this lack of care are evident in a recent compilation made by the United States Public Health Service in which it was found that 6,099 school children attending semi-rural schools practically without medical supervision, lost through illness 37,153 days from a possible 666,449 days of school attendance. A large part of this might have been prevented by adequate health supervision. Surely it is time that the " little red schoolhouse " should be supplanted by a modern up-to-date building equipped with the best appointments for health and education.

434. Child Welfare Clinics. — These are clinics to which babies can be brought and examined free. They are usually located in the poorer parts of a city among those who are ignorant of the best scientific methods of care for babies. An attempt is made to introduce proper feeding. The mothers are given instruction in the clinics and the nurses also go into the homes to show the mothers how to care for their babies. It is an attempt to carry preventive medicine to the people and thus reduce the death rate among the class of people where it is the highest.

The greatest safeguard against many diseases is a vigorous body. To possess a vigorous body certain well-known health laws must be complied with. Some of these have to do with a supply of pure air, well selected and clean food, healthful occupations, rest, and recreation. Some boys and girls are in poor health because of diseased tonsils or decaying teeth, whose poisons are pouring into the system and prevent the development of a vigorous body, which is, as we have said, the best safeguard against most diseases.

There is a group of hygienic measures that, when practiced, keep us in good health under normal conditions. When the normal body is underfed, dirty, without proper clothes, or when the tonsils are diseased or the teeth are uncared for, the normal resistance to more serious germ diseases is dangerously lowered. All such conditions hinder the regular growth of the body.

To correct as many of these conditions as possible, health directors, school nurses, and school physicians make regular inspections and inform parents about the health of their children. This work is under the general direction of the State Board of Health and is doing much to insure a generation of healthier boys and girls.

435. The Anti-tuberculosis Campaign. — It is the general theory of medical science that a very large percentage of human beings have had a mild form of tuberculosis in youth, and during this period have acquired immunity to these germs. This conclusion has been reached after discovering the remains of an early infection in a large number of human bodies whose death has not been due to tuberculosis but to some other cause. Another generalization follows from this belief, *i.e.* that a recurrence of tuberculosis may follow without a new infection when the body becomes exhausted and is in poor health. So important is this disease that most states have made a special division for it in their health departments, as already stated for New York State. Then

there are independent private charitable organizations, with national and international activities, that are devoted to the eradication of tuberculosis. The Rockefeller Foundation has been assisting in this work in various countries of Europe.

Nearly every county in New York State has either a tuberculosis hospital or has arrangements whereby it can send its needy sufferers to such a hospital. In these institutions, incipient cases are trained to care for themselves. If the care can begin early enough, a cure is usually effected. Such persons are taught how to live and are able to tell others how they should live. Through this splendid campaign a great deal of valuable biological information has been brought to hundreds of thousands of people. There is no way of estimating how many people have been aided in preventing this dreadful malady.

The same hygienic measures that are good for tuberculosis are beneficial to the general health of every one of us.

436. National and International Public Health Activities. — The responsibility for keeping the water and food in a pure condition is often more than one state can manage, and the control of some of these activities has been taken over by the National Government. In the same way there has grown up a conviction that one nation cannot adequately regulate conditions when a world-wide distribution of a disease exists. For example, malaria and yellow fever exist in all parts of the tropics. Leprosy is almost wholly an Oriental disease. Cholera and typhus fever are confined mostly to the eastern hemisphere; while hookworm belts the world in an area about 20 degrees each side of the equator. Such conditions call for international coöperation, and the Health Division of the League of Nations is such an organization.

Some notable instances of epidemics have followed the eating of oysters from localities where sewage from rivers has poured into the ocean where oysters and clam beds

are found. The regulation of the collection of shell-fish would thus naturally come under the National Government because it often happens that the territory of more than one state is involved.

Our National Government has a splendidly organized department of Public Health and Research Laboratories. The workers in these have found that special regulations have to be adopted when a large number of men are in temporary camps as the army moves from place to place. The work of the army in public health education has been an important factor in increasing our general information.

437. National Quarantine. — Strict quarantine regulations are enforced by the National Government upon boats coming from ports where certain diseases are prevalent. Regular inspection of all immigrants is made before they are permitted to land.

Some conception of the extent and exactness of such quarantines as applied to animals and plants can be gained from a knowledge of insect pests and the regulations governing them, and the importation of plants.

Insect Pests. — Most of us never realized how many different kinds of insects there were that feed upon even garden vegetables until we tried to do our part by caring for a war garden. Nearly all the thousands of plant diseases and pests that go to make the life of the farmer, gardener, or orchardist unhappy, and greatly to reduce the size or entirely destroy his whole crop, a few years ago occupied but small territories. So far as our information goes more than one half of the insects that cause incalculable losses to our fruits and vegetables came from foreign countries. They may be said to have migrated to the land of plenty, for in their native homes either the amount of food was limited by the growing of small crops or their natural enemies were so numerous that they were themselves destroyed before they could do any marked damage.

One of the early pests to be introduced into America was the Hessian fly, which was brought over in the straw used to bed the horses of the Hessian soldiers in the Revolutionary war. The litter from the stables was thrown ashore in New Jersey, from which region it soon spread to all sections. This single immigrant insect destroys as much wheat each year as, if marketed, would pay the entire expense of the Revolutionary war.

At first thought it seems strange that the government of the United States should have a quarantine against insects landing at our seaports, but that is just what the Federal Plant Quarantine Act of 1912 means. One department of our government is turning its attention to little insects in order to save American agriculture by preventing any more kinds of insects from entering the United States.

Fruit-flies. — Some of these insects of other lands that are serious pests are popularly known as fruit-flies. They resemble house-flies, but are of more attractive appearance, inasmuch as their wings are prettily spotted and banded and their bodies are usually more brightly colored. They are like house-flies also in that they lay small eggs that hatch into whitish maggots. These maggots feed upon the living tissues of fruits, nuts, and vegetables. Eggs are laid just under the skin of the fruit, and these eggs hatch into maggots that burrow in all directions. As the maggots tunnel about they cause decay to develop, and these decaying areas produce greater injury than the maggots themselves. In order to destroy fruit-flies, the Plant Quarantine Act prohibits the entry of all horticultural products likely to carry insect pests unless they have been rendered free from danger as pest carriers.

The Bermudas probably would not now be infested by the Mediterranean fruit-fly had not a sailing vessel, bound for New York from the Mediterranean region during Civil War times, been blown from her course and forced to unload her

cargo containing infested fruits at St. George. The Mediterranean fruit-fly did not become established in Australia until steamships and cold storage made it possible for the infested Mediterranean countries to ship oranges to Perth and Sydney. With the pest established in eastern Australia the ships plying between Australia and Hawaii carried the maggots to Honolulu, and to-day the inspectors of the state of California and of the United States are intercepting infested fruits on ships arriving at San Francisco and San Pedro from Honolulu and Hilo.

Some conception of the extent to which restrictions are placed is gained from the following list: Importations of certain fruits from Mexico are prohibited; also all pines from Europe, and five-leafed pines from Asia, Canada, and Newfoundland; alligator pear seeds from Mexico and Central America; all citrus fruit stock from all foreign countries; Indian corn or maize and closely related plants from India, Siam, China, Malayan Archipelago, Australia, New Zealand, South Sea Islands, Philippines, Formosa, and Japan; sweet potatoes and yams from all foreign countries; banana plants from all foreign countries, including Hawaii and Porto Rico.

438. Work of Special Health Agencies. — The Rockefeller Institute for Medical Research is distinct from the Rockefeller Foundation. Its purpose is indicated in the charter as being devoted to "medical research with special reference to the prevention and treatment of disease." Several notable discoveries in regard to antitoxins and the conditions regulating the growth of cells under normal and abnormal conditions have already been made.

The Rockefeller Foundation was chartered in 1913 to promote the well-being of mankind throughout the world. The large resources of this private foundation are almost entirely spent on public health and medical education. The trustees of the foundation have contributed several

millions of dollars to the establishment of schools of hygiene and public health at the Johns Hopkins and Harvard universities, as well as supported medical education by large additional gifts to selected medical schools in the United States, Canada, England, and China.

During the year 1922 demonstrations on hookworm control were carried on in eleven southern states and twenty-two foreign countries, which gave this foundation an international activity. In a similar way their work on malaria and yellow fever took on an international character, for the control of such diseases is not a local problem. Prevention requires that the causes be eliminated, and this no state or nation can do without the coöperation of all of the countries where the cause exists.

The discoveries of scientists constitute an absolutely essential step, but unless these discoveries can be made effective by being put into practice, they are of no avail. For instance, scientists learned that certain fish were very beneficial because they fed on mosquito larvæ, but it was necessary to distribute these fish in the regions where malaria and yellow fever were prevalent before any benefit could result. The Rockefeller Foundation helped to introduce these fish (Figure 262) into Mexico during 1922.

The League of Nations has a special division, the Health Section, which has been doing remarkable work in the devastated and famine-stricken regions of Europe. The Rockefeller Foundation has been coöperating with this organization by helping to finance its work, which is of inestimable value in the preservation of the public health of Europe and Asia.

The name of the Memorial Institute for Infectious Diseases, founded in memory of John Rockefeller McCormick in 1918, was changed to the John McCormick Memorial Institute for Infectious Diseases in 1918. This institution, located in the city of Chicago, consists of a laboratory and hospital. Diphtheria, diphtheria carriers, measles, scarlet

fever, and certain of the respiratory infectious diseases have received critical attention in this research institution. The discovery of the germs of scarlet fever was announced in 1924 by this institution.

The Carnegie Institute of Washington was founded by Andrew Carnegie on January 28, 1902. The articles of incorporation declare that the object shall be " to encourage in the broadest and most liberal manner investigation, research and discovery and the application of knowledge to the improvement of mankind." We are particularly interested in the biological departments of research. (1) The Department of Genetics and Experimental Evolution located in Cold Spring Harbor, Long Island, N.Y., is chiefly devoted to the theoretical studies of heredity and evolution, and the application of heredity to human beings. (2) In the Laboratory for Plant Physiology at Tucson, Ariz., research activities are carried on in desert vegetation with especial attention given to their adjustments to the arid conditions. (3) The Department of Embryology, located at the Johns Hopkins School, Baltimore, is concerned chiefly with human embryology. (4) The Nutrition Laboratory, Boston, Mass., devotes most of its researches to discovering the fundamental laws governing our vital activities. It has been necessary to invent many complicated pieces of apparatus in order that exact measurements can be made on human beings undergoing fasting, or exercise experiments. So far the results abundantly justify the large amount of money that has been expended. It will take many years to solve these problems accurately. (5) The Department of Marine Biology, located at Tortugas, Fla., is given over to the study of marine tropical life.

The American Society for the Prevention of Cancer was organized in 1913 and is devoting its research activities to these abnormal growths, which we do not as yet understand. There are similar organizations in London and Paris.

The Millbank Memorial Foundation of New York City is another private organization that is making a critical study of tuberculosis and its prevention. It is just beginning its activities, so that it cannot be stated what special phases will be emphasized.

Any enumeration of important public health activities that did not take into consideration the Red Cross, an international and national voluntary society, would be omitting a very important organization. The Red Cross holds itself in readiness to offer the best scientific assistance that can be given in times of great emergencies, such as the San Francisco earthquake and fire, the flood in the Ohio Valley, or the recent Japanese earthquake, as well as in time of war.

The work of these several Public Health agencies varies from year to year, and you will find it interesting to make a special study of their work during the year that you study biology.

439. Modern Surgery. — Modern surgery began with Sir Joseph Lister, who in 1867 announced his practical application of the germ theory to wounds. He said: "When it had been shown by the researches of Pasteur that the septic property of the atmosphere depended, not on oxygen or any gaseous constituent, but on minute organisms suspended in it, which owed their energy to their vitality, it occurred to me that decomposition in the injured parts might be avoided without excluding the air, by applying as a dressing some material capable of destroying the life of the floating particles."

This method of Lister, greatly modified and improved, has been universally adopted. Until Pasteur or some one else discovered germs and the fact that they gave rise to fermentation changes, the marvelous results of Lister were impossible. Pasteur did not ask whether the study of fermentation had any relation to man or not, when he was carrying on his epoch-making discoveries. He was simply

trying to discover what principles governed fermentation. We never know just how valuable a scientific discovery will turn out to be any more than we can predict just what great contribution to human welfare some of you may make.

Modern surgery takes great care to prevent germs from getting into the openings which have been made to correct some abnormal condition. The knives and other instruments are sterilized. The air in the operating room is dust free. The surgeon and nurses wear masks so that germs from their noses or throats may not escape into the air. This is *aseptic* surgery. In *antiseptic* surgery less care is used in the operating room, but all cuts are treated with germicides to kill the germs that may have entered. A strong human body may manufacture its own antitoxin and thus neutralize the poisons of such germs as are not killed, and the patient make a good recovery. The advantages of aseptic surgery over antiseptic surgery are self-evident.

440. Insulin. — Whenever a discovery is made that helps to relieve suffering and prolong life, popular interest is immediately stimulated. It has been known for many years that the disease called diabetes was immediately due to the failure of the body to burn properly all of the sugars that were eaten as food. Scientists had been working for more than fifteen years to isolate from the pancreas the particular substance that helps the body to utilize the food sugar. They centered their interest on the pancreas because certain cells of the pancreas were failing to act normally. Finally Dr. Banting of the University of Toronto succeeded in 1922 in isolating from the pancreas the specific substance that stimulates the body in such a way that sugar is utilized. This substance is known as *insulin*. A word of warning is necessary in regard to the use of insulin because it is *not a cure* for diabetes but merely relieves the symptoms. A large number of scientists are working on the several problems that this discovery has helped to solve, and we may expect to learn a great

deal more about the use of insulin and possibly the prevention of diabetes within the next few years.

441. Conservation of Biological Resources. — The wholesale destruction of game represents a distinct loss to all lovers of out of doors and often creates a serious situation, for the destruction of selected groups of animals usually upsets the balance in nature. This may allow the enormous multiplication of harmful animals or result in the elimination of beneficial ones. Already the reduction in the number of birds has permitted the development of harmful insects in our orchards, and to eliminate them requires a large outlay of time and money in order that we may raise good fruit.

Through the Reclamation Service water has been conducted into desert regions and now great crops of food are annually harvested where previously sagebrush and cactus were the chief plants that could live.

Under the direction of the National and State governments, large sums are spent annually to help us use our biological resources more intelligently.

Game Laws. — The United States Department of Agriculture issues annually a pamphlet containing a summary of the laws of the United States, Canada, and Newfoundland, relating to trapping, open seasons, propagations, and bounties. By the adoption of strict regulations there is gradually coming into existence a realization of the importance of conserving our wild animals. By offering suitable bounties the destruction of such harmful animals as wolves and coyotes and the destructive rodents is being effected.

442. New York State Conservation Department. — This is a separate department and is concerned with the care and protection of the forests, and the fish and game in these forests and inland waters. It also has supervision of forest nurseries, reforestation, hatcheries, game farms, and the conditions under which vacationists may camp on state land.

Supplementing the work of this department, the State

Agricultural College, the State Forestry College, and the State Experimental Station carry on researches and train men to understand the necessity of conserving our plants and animals.

Specifically the work of the New York State Agricultural Station takes up such problems as the following. From the early days of the Station's existence, down to the present time, an effort has been made to test every variety of hardy fruit that will grow and to see in what way it can be improved. Much attention has been given to the breeding of new fruit. More than thirty thousand seedlings of various sorts have been grown, and from these over sixty new varieties of different fruits have been secured which were deemed worthy of naming and distributing to fruit growers.

The work of this station in studying plant and animal diseases has been very great. In fact, it is probably not too much to say that only because of the tireless efforts of entomologists and plant-disease specialists is marketable fruit possible.

Extensive and original experiments have been carried on in connection with the milk supply. A quick and easy method has been devised for the direct counting with the microscope of the bacteria in fresh milk as it is brought from the farm. The application of this method is of great benefit in quickly determining whether milk is fit to use or not. Such experiments as these indicate that if the station is to serve the state and nation effectively, it must lead the way into new fields of endeavor and not be content simply to follow the trend of the times.

443. The United States Fish Commission. — The Bureau of Fisheries is one of the subdivisions of the United States Department of Agriculture. In this Department are carried on studies dealing with problems of national importance concerning the sources of food from the sea and the great inland lakes such as Michigan, Superior, and others. Early

studies upon the life of lobsters and fishes revealed the fact that a great many of the young were eaten before they had an opportunity to mature. This suggested the desirability of establishing hatcheries where young could be hatched and protected until they were old enough to secure their own food and escape their enemies. The United States Government supports a number of such hatcheries. This is also true of New York State, where hundreds of thousands of trout and bass eggs are hatched annually.

Just now lobster fishing is of major interest. The United States Bureau of Fisheries has endeavored to transplant lobsters to the Pacific coast with little success. However, there seems to be no reason why it should not eventually succeed. The success of this enterprise would greatly increase the annual output. Lobster fishing on the Atlantic coast is declining. Great improvements in the management must be instituted if this business is to continue to be profitable.

444. The United States Biological Survey. — This is another division of the United States Department of Agriculture. It is the bureau of information on all matters pertaining to game and wild-life protection, economic value of birds, routes and migration habits of birds, and, in general, the informational side of such biological questions. As an example of the use made of its fund of knowledge, we can cite its recommendation of a law prohibiting the importation of the mongoose.

This animal which is said to combine the ferocity of the mink, the agility of a squirrel, the penetration of a ferret, and the cunning of a rat, has caused no end of trouble in Jamaica, Cuba, and some of the Hawaiian Islands, where it was introduced for the purpose of destroying rats. It not only destroyed rats, but when these were gone it started in to exterminate all of the wild birds and domestic fowls of the island. If such an animal were introduced into the United

States, you can easily imagine what damage it would do to our game birds, song birds, and domestic fowls.

This Department has issued a considerable number of pamphlets describing the life history, food habits, breeding habits, and general activities of our wild animals. These bulletins can be secured by writing to the Department of Agriculture. The activities of this Department in helping the western farmers to destroy the numerous rodents that feed upon their grains, has been of immense importance.

One would expect to find all mammals under the supervision of the biological bureau. But this is not so. The fur seals which have become so valuable financially, are under the direction of the Bureau of Fisheries, as these animals live in the ocean, and the ocean life is all under the direction of the Bureau of Fisheries.

One would also expect that the care of our national parks would be under the supervision of the Department of Agriculture, but this is not so, and we look to the Department of the Interior for the supervision and regulation of these parks. All of these agencies in whatever bureau in the state or nation they happen to be placed are established for the conservation of biological resources.

445. Conservation and the Future. — The death rate among human beings is being lowered by applying the results of scientific discoveries about health and disease. Wild animals are being preserved in the " sanctuaries " and regulations protecting our wild flowers are becoming more general. Destructive insects and harmful plants are being kept out of the United States. The National Government is cooperating with the state departments in their endeavor to control the cotton boll weevil and the European corn borer. International coöperation is bringing under restraint world-wide diseases that destroy man, animals, and plants.

Advance in science must wait for the work of individuals who have those qualities of mind that enable them to solve

problems that no one else has yet been able to solve. We are too prone to pass lightly by great minds, although daily we enjoy the results of their labors. Let us pause a moment and tender to them our sincere obligations.

Dr. Charles Wardell Stiles of the United States Public Health Service discovered hookworm and the methods of cure. This contribution alone made many millions of people debtors to him. His marvelous discovery did not make him any richer in money but it did give to him the greatest satisfaction that ever comes to any human being. The men who lost their lives trying to discover the cause of yellow fever and the value of X-rays in the treatment of disease, are among our greatest national heroes. They died trying to find out a method by which the lives of millions of people might be prolonged. A nation is safe when it has such heroes. It is in danger when it forgets them.

OUTLINE

- Health activities
  - Municipal
    - Water supply
    - Sewage
      - Disposal
      - Purification
      - Septic tanks
    - Milk supervision
    - Other foods
    - Quarantine
  - State
- Supervision of children
  - Country schools
  - Child welfare clinics
  - Anti-tuberculosis campaign
- National and international activities
  - National quarantine
    - Insect pests
    - Fruit-flies
  - Special agencies
    - Rockefeller Institute
    - Rockefeller Foundation
    - League of Nations
    - McCormick Memorial Institute
    - Carnegie Institute
    - Minor organizations
- Modern surgery
- Insulin
- Conservation of biological resources
  - Game laws
  - N. Y. State Department
  - U. S. Fish Commission
  - U. S. Biologic Survey
- Conservation and the future

SUMMARY

Conservation of animals, plants, and human beings is the greatest problem that we have to solve. Immense progress has been made through scientific discovery. Municipal, state, national, and international agencies are making effective these discoveries. Many private agencies are making great contributions to conservation through their researches and by distributing the new information all over the world.

QUESTIONS

What is conservation? Why did not conservation begin a hundred years ago? What must be done before conservation activities can be effective with the cotton boll weevil? What is public health? How is it carried on? Why are laws necessary in connection with public health activity? What conclusions do you draw when you discover that a country has practically no health laws? Name some of the agencies that are helping the advancement of public health. Why should there be conservation of biological resources? What agencies are doing the most in this regard?

Shirk Monday

CHAPTER XXXVII

BIOLOGY AND HUMAN PROGRESS

From lower to the higher next,
Not to the top, is Nature's text;
And embryo good, to reach full stature,
Absorbs the evil in its nature.

— LOWELL

Whenever we compare the things that we can do, the pleasures that we enjoy, the clothes that we wear, our knowledge of disease, with those of our fathers we discover that important progress has been made. This progress shows the extent to which man has gained control of his environment and the use that he has made of this control. In a general way our environment has not undergone much change in the last thousand years, and yet our control over it has undergone more change during the past hundred years than in any previous thousand years.

This change is due largely to two factors: first, scientific discoveries; second, the intelligent application of these discoveries to everyday life.

446. New Discoveries. — If our universe has remained about the same during the past thousand years, how can there have been so many new discoveries in recent years? This question can be easily answered. When some one finds a new animal or plant and announces that he has discovered this animal or plant, it simply means that man has seen and described it for the first time. This kind of animal or plant may have been living in this same region for hundreds of

years. It is the same when some one makes a new discovery in physics or chemistry. He recognizes relationships that no one else has ever noticed.

All new discoveries have been made by men and women who once were just boys and girls as you are, with possibly no notion of the way that they were to help to make this world a better place to live in. Every one of us is anxious to do some little thing to improve the conditions under which

Photograph furnished by Cornell University.

FIGURE 410. — TIMOTHY HEADS.

people live. There is still much to be learned about the relations of plants and animals to man and some of you should prepare yourselves to have a part in this great work. So much has been learned that it will be necessary for you to spend a number of years before you will have sufficient training to undertake to solve any of nature's secrets.

In this chapter a brief account of the value and character of new discoveries in connection with improving plants and

animals, the relation of heredity and variation to progress, will be given.

447. Improvement of Plants and Animals by Breeding. — In Figure 410 is shown a photograph of the different sizes in the heads of timothy hay. The variations have to do with the length, thickness, and form of the head. In these heads are grown the seeds which are valuable as food to animals and which are used as seed when the farmer wishes to raise a crop of hay. Figure 411 shows the practical value of planting seed that yields a large crop instead of a small

Photograph furnished by Cornell University.

FIGURE 411. — BUNDLES OF TIMOTHY RAISED UNDER IDENTICAL CONDITIONS FROM THE SAME AMOUNT OF SEED.

It pays to plant good seed.

one. In each of the five bundles in this figure, the same amount of seed was planted in the same kind of soil. It is unprofitable to use poor seed.

In order to furnish the farmer with the necessary information upon all such subjects, scientific experts have been and are now devoting a great deal of time to experimentation. The following example shows the importance of such study in helping man to produce new and better kinds of plants and animals.

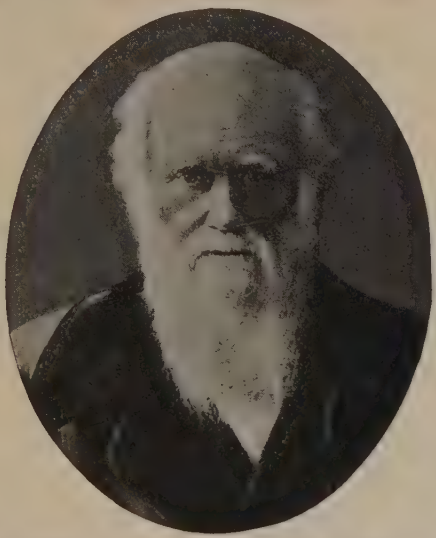
Figure 412 consists of bearded wheat, the pollen of which was placed on the stigma of the wheat flowers that formed on the non-bearded wheat shown at the right in the figure.

When the kernels of wheat in this head ripened, they were sown and a plant was produced which grew a longer head, having practically no beards (the middle head in Figure 412). Such a head of wheat would yield more kernels than either

Photograph furnished by Cornell University.

FIGURE 412. — HEREDITY IN WHEAT,

The head of wheat on the left of this figure has beards. The pollen from the wheat flowers of this head was placed on the stigma of the wheat flowers that grew in the head shown in the right wheat head of this figure. When these kernels of wheat ripened, they were sown and produced a wheat plant that had more wheat kernels than either parent. This is the head shown in the middle.



Charles Darwin (1809–1882) made many original observations on animals and plants and conducted numerous experiments with them. But he was not satisfied simply to discover new facts; he wished to find some explanation for them. Just how all of the many forms of life came to live where they do and to have the size and habits that they do is hard to determine. Darwin believed that there was a natural struggle continually going on in nature between the weak and the strong, and that some which could run faster or eat more kinds of food were able to live in the competition while the ones that lacked such ability died. He formulated a number of explanations (theories or hypotheses). The best known of these theories is the Origin of Species by Natural Selection.

The main idea emphasized by Darwin in this theory is that life has gradually unfolded or evolved (hence evolution) passing from the simpler types like sponges or hydra to the more complex, gradually becoming more complicated as the division of labor sets organs more and more apart.

Darwin, himself, was conservative and reverent, as the following from the closing sentences of his book on the Origin of Species shows :

"There is a grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity from so simple a beginning, endless forms most beautiful and most wonderful have been and are being evolved."

of the parent heads. Now if the scientific expert can make this new wheat plant permanent, that is, produce seed that will always grow large heads, he has furnished the farmer with a new kind of wheat and has made a new discovery.

Another example of the way in which scientific experts study the question of improving plants and animals is shown in the study of the resistance of grapes to disease. The American grape is a North American plant including from fifteen to twenty-five different species, about one half of the total number known to man. These different kinds of grapes grow in varied areas and climates. Their original distribution over North America was due to animals, such as birds, and to river currents.

FIGURE 413. — LEAF GALLS ON GRAPE CAUSED BY GRAPE PHYLLOXERA.

The roots are also injured by this disease, which threatened to destroy all of the European vineyards.

The several varieties of American grapes are descended from an original species which has become changed by environment until we find types of grapes as diverse as the regions in which they are found.

Many of these varieties have been in existence since white men came to this country. During this time they have acquired a strong resistance to certain parasitic diseases which are very destructive to the European grapes. Among them is one that is caused by a minute plant louse that lives either

in the leaf, stem, or root. This insect is known as *phylloxera* (fĭl-ŏks-ḗ-ra). In addition to this animal disease, there are three plant parasite diseases: black-rot, downy mildew, and powdery mildew. Each of these four diseases is able to kill grape plants, and more than one may attack the same plant at the same time.

A few years ago these diseases became so widespread in Europe that they threatened to destroy most of the European vineyards. Many experiments were undertaken to save this valuable industry. It was discovered that the European grapevine could be grafted on to the root of any one of several of the American grapes, and when these vines were thus grafted they were found to possess a resistance to all four diseases, with the result that the vineyards of Europe were saved.

This success was due to scientific study, which discovered the difference between the European and American grapes in their power to resist disease, and the fact that the quality of the European grape would not be altered by grafting it on the roots of the American varieties. Here we have an illustration of variation that is not confined to the shape and size of the parts but to their resistance to disease. This may be described as an *acquired immunity* that is transmitted by heredity from one generation of grapes to another. The word *immunity* used in this last sentence was explained on page 418.

These examples introduce us to a large number of results that scientists have secured, which are of great benefit to man. The sugar content of corn has been increased, seedless oranges and grapefruit have been developed by breeding experiments. The Holstein breed of cows is famous for a large yield of milk, while the Jersey gives milk that is very rich in butter fat. The heavy draft horse that you see hauling great loads is poorly qualified for racing, and yet the draft horse and race horse are both the product of experi-

mental breeding. One of the most striking illustrations of the extent to which such breeding can be carried is seen in any large exhibit of poultry. At the New York State Fair more than one hundred different classes of poultry are shown each year.

What does the scientific man do who makes such discoveries? He starts out to tell just as many people as he can that he has made a new discovery and to ask them if they do not wish to try it. In order that as many people as possible shall have an opportunity to know about his new discoveries he writes a description of them and sends them to some scientific journal. He does not get any pay for his scientific articles, as do writers of stories, nor does he have his articles copyrighted, but he invites any one who wishes, to use his facts.

Thus new ideas are constantly being furnished through the investigations of the hundreds of scientists throughout the world. These new ideas keep one informed about the way other people do and help to make one broad-minded and progressive. New ideas and new discoveries, however, are of no value unless they are utilized.

448. Heredity. — An easy way to understand the technical meaning of this term, which we use so frequently, is to make a study of your hand. Normally we all have four fingers and one thumb, but our hands are quite unlike. This is readily seen by comparing the three hands in Figure 414. The large one is the hand of father, the middle one of daughter, and the right one of mother. The first and the last fingers of the father's hand are about the same length, while the little finger of the mother is much shorter than her first finger. The difference in the length of these two fingers is repeated in the hand of the daughter. We say that the daughter inherited from her mother a short little finger and a long forefinger.

Now if we study the position of the thumb in its relation

FIGURE 414. — HEREDITY SHOWN BY COMPARISON.

Photograph of hand of father at the left, of mother on the right, and of daughter in the middle. Which parts of the daughter's hand are like her mother's? Which like her father's?

to the palm of the hand, it is seen that the distance between the thumb and the base of the forefinger is proportionately greater in the hand of father than of mother. The same is true of the hand of daughter. When she grows to maturity, this distance will be much greater than it is in the hand of her mother. The daughter inherits this peculiarity in her hand from her father.

Make a study of the several parts of your own hand and compare your hand with the hand of your mother and father. This study will show you what is meant by the term heredity as applied to your hand.

In a similar manner you can compare the color of your eyes and hair; length of arm; shape of head; muscular vigor; size of body; intellectual traits, such as interest in language, history, science, or business; and temperament, which includes liveliness, deliberateness, excitability, quickness, or slowness.

After you have made these comparisons, you realize that you are unlike both parents in that you have some features which are lacking in either your father or your mother. The total of the like parts and traits which are the same as in your father make up what you have inherited from your father; and the total of the parts and traits which are the same as those in your mother, make up what you have inherited from your mother. Thus we inherit from both parents.

But there are usually found some structures and characteristics that do not represent anything found in either parent. If such are carefully analyzed, it is usually discovered that they exist in some of the grandparents. It is always interesting to try to locate their origin.

This study of our hands and other parts of our body leads to an important general statement. *All the parts of your body with their individual peculiarities have existed in other human beings and these persons were your immediate ancestors* (parents, grandparents, great-grandparents, etc.).

This explanation of heredity applies to all animals and plants, so that we can study heredity in our own gardens or with our pet animals.

There is a limit to the differences that exist between child and parent, and these differences under normal conditions produce changes that would never make the structure a new one; for example, the finger is always a finger, and hair is always hair. Heredity is thus a descriptive, technical word used to explain the like parts between child and parent.

FIGURE 415. — GREGOR MENDEL.
From a photograph taken about the year 1862.

449. The Mendelian Laws.—The Austrian Monk, Johann Gregor Mendel, used the leisure time that he had from his duties to experiment with plants in the garden of the monastery. His results were published in an obscure journal in 1866 and he died in 1884, before scientific men had become acquainted with his remarkable investigations, for it was not until 1900 that similar experiments were made in Holland, Austria and Germany, England, France, and America.

Through a method of investigation, devised by Mendel, heredity is rapidly becoming a more exact science. Mendel's experiments were concerned with crossing varieties of peas which differed in size, color, or form. These experiments extended over about eight years and include a large mass

of information. We can only illustrate some of the simpler conclusions.

Two of the pea plants selected for experimentation differed in the color of the pea. In one they were green and in the other all were yellow. Now when the pollen from the plant of the green peas is placed upon the stigma of the plant with yellow peas, or just the opposite experiment is tried, and these ripened peas are planted, all of the peas will be yellow as in Figure 416. This plant is called the *first hybrid generation*. It is called a hybrid because of this crossing between the two kinds of plants.

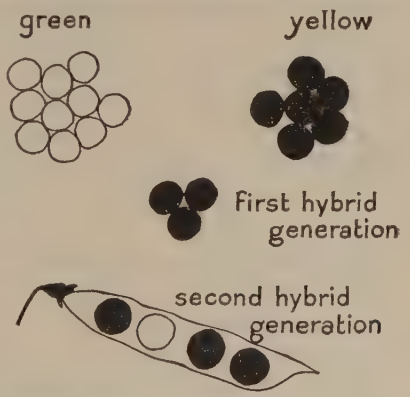


FIGURE 416. — DIAGRAM TO ILLUSTRATE SIMPLE MENDELIAN INHERITANCE.

Now if the pea flower of this first hybrid generation is self-pollinated and then the ripened peas are planted, there will be found in the pea pods green and yellow colored peas, in this *second hybrid generation* (Figure 416). The green color appeared to be absent in the first hybrid generation. It was really concealed by the fact that yellow dominated the green. This is the first and most important law of Mendel and two descriptive words are used to make it clear. The yellow color is said to be *dominant* and the suppressed color, green, is *recessive* (hidden).

This same idea was illustrated in comparing the hands in Figure 414. The length of the little finger was not intermediate between that of the two parents. The shortness of the little finger was dominant in that particular cross over the long little finger of the father. In Mendel's actual experiments he obtained 6,022 yellow peas, and 2,001 green

colored peas, thus giving a nearly exact ratio of 3 : 1. Now if the green colored pea shown in the pod in Figure 416 is planted, it will give rise only to green colored peas. If the three yellow peas are planted, however, some of these will give rise to yellow and some to green, and the ratio will continue approximately of three yellow to one green. In man, eye color has been found to be inherited according to this law of Mendel.

Mendel's method of investigation has now been applied to a very large number of animals and plants. Large books have been written, describing these results. From all of these studies it appears that the many peculiarities exist as separate parts, such as, the long or short little finger, the green or yellow color in the pea. Scientists call these differences, *characters*, and so in stating Mendel's law they say, " Characters are represented in the germ cells by units which tend to segregate or combine in definite proportions," such as was shown in the three to one ratio in crossing peas.

450. Eugenics. — There are two ways of bringing about human progress. The first is by improving the environment, the second consists in seeking a better inheritance with which to begin life. This is called *eugenics* and is defined by Galton, the famous English student of heredity, as *the science of being well born*. In 1916 there were nearly 395,000 inmates in 576 institutions in the United States, costing the people in taxes over $81,000,000, for that year. The inmates of these 576 institutions were insane, criminals, dependents, feeble-minded, deaf, or inebriates, all showing inferior mental qualities.

Two notable defective family histories have been investigated, namely, the Jukes and Kallikaks. The Jukes family shows a history of 709 descendants of Max Jukes who was a shiftless backwoodsman. One half of the children died in infancy, and of those who lived, there were 310 paupers, and over 30 convicted criminals. The cost to the state in main-

taining and prosecuting this band of crooks has been over $3,000,000.

The Kallikak family show in a striking fashion that mental deficiency when once started may persist for many generations; 481 descendants were traced from a feeble-minded mother, giving 143 feeble-minded children and 291 who were inferior in intellectual ability. In this same family there are 496 descendants from an intelligent mother and only two show any indication of subnormal mentality, while the other 494 were successful citizens in their several communities.

In these two tragic illustrations mental deficiency made a poor parent and there was a long line of poverty, misery, sin, and crime. It is important that we should realize that culture, refinement, intelligence, and all of the desirable traits present in man are likewise inherited. In all of the great countries of the world, we find a long list of eminent men who are related by direct descent. In the Bach family there are 20 eminent physicians and over 40 less eminent. The Darwins became noted for their scientific ability two generations before the birth of Charles Darwin. Erasmus Darwin was an eminent man. He had a son Robert who was a distinguished physician. Robert was the father of Charles R. Darwin, who is regarded as one of the greatest men of science. The four sons of Charles Darwin all became prominent. One of the descendants, Francis Galton, a cousin of Charles Darwin, is one of the most famous students of heredity.

In America we have the famous family of Edwards. Jonathan Edwards was a noted New England clergyman. In 1900, 1,394 descendants were known. Among these there were 295 college graduates, 13 college presidents and many school principals, 60 physicians, many of whom were eminent, 100 clergymen, 75 officers in the army and navy, more than 100 lawyers, 30 judges, and 80 who held public office.

The contrast between the Jukes and the Kallikak families

on the one hand, and Bach, Darwin, and Edwards on the other, clearly indicate that good inheritance is the most priceless gift that ever can come from parent to child.

Thus general ability and a tendency to industry and thrift are qualities that can be inherited. The men and women who possess such mental traits carry on the business of the country and pay taxes, not only to support the government, but also to care for the idle, the shiftless, and the criminal. If we have inherited these, we should strive to keep them unimpaired and to strengthen them, so that we may pass them on to our children, in order that the next generation shall possess men and women who will be able to advance human progress beyond our best effort.

451. Mental Health. — We have placed a great deal of emphasis in this book on the care of the teeth, good digestion, a healthy body, and the prevention of disease. All of these are very important. But physical health is not all we need; biologists are studying the problem of mental health as well, in order to devise ways of helping us to understand this part of our life. It represents one of the new fields of beneficent research.

Biology is intimately associated with everything that has to do with disease. Our minds may become diseased and insanity may follow. During the years 1917–1922 more than 68 thousand persons from 21 states were admitted into 68 state hospitals for the insane. Four per cent of these were associated with alcoholism; 47 per cent were due to *faulty mental adjustment*. Thus, one half of this large number might be said to have become insane unnecessarily.

The time has come to recognize that certain phases of insanity are preventable. You should try to keep your mind as clean and healthy as you do your body. Try to enjoy yourself when you work as well as when you play. Your companions should be good books and good friends. In just the same manner that you get pleasure from your

friends, let them enjoy you. Natural healthy recreation such as scouting is of great value in giving you a correct view of yourself and others. It is a splendid thing to have a plan about what you are going to become when you grow up. A young boy once wrote an essay on " Why I want to go to School." It was very short, " I am going to school so that I can enjoy my mind." This needs to be enlarged so that we can say, I am going to school so that I can learn how to live and can help others to live. This simple plan for our lives will do much to prevent mental breakdowns and make us fit to be citizens of our great democracy.

452. Environment. — All through this book attention has been directed to the environment in which the animal or plant, that was being studied, lived. The same fact was emphasized in the beginning of this section dealing with human biology. When the environment of man is critically studied, it is noted that it may have a large influence upon him. Even though he may have inherited a strong body and a tendency to thrift and industry, he may find himself in a social environment that is so strong that he has great difficulty in earning enough money to keep alive. When the full influence of environment was appreciated, men and women began to insist that better housing conditions and a certain amount of fresh air and light must be provided in order that those who lived in the tenements should find it easier to keep well and thus be able to work. Even though their environment is not of the best, it is possible for them to become superior to it.

In the steady advance which human progress is making, the conditions under which men and women live and work are constantly growing better. As these conditions improve, there will naturally follow a larger opportunity for our inheritance to have its full influence upon us. Two noteworthy movements are already having a marked influence in this direction; namely, the prevention of the spread of bio-

logical diseases and the child welfare movement (see page 633). As we gain a clearer conception of the importance to man of variation and heredity, other movements will be undertaken to place man in greater control of his environment.

The fact that biology stimulates us to think about all such problems is one of the main reasons for studying it. But with all this scientific information at our disposal, much remains for the individual to do. He must realize his obligations and opportunities in the age in which he lives. A mere passive existence has never accomplished anything worth while. The desire to serve our country and our fellowmen and a personal ambition must be added to our scientific information, if we would attain real success.

453. Biology and Progress. — In tracing the progress of the history of biology you will find the names of many eminent men, who possessed marked ability and industry. One of the earliest men to make a great contribution to our subject was the famous Greek, Aristotle, who collected large numbers of animals and dissected them. He lived more than 300 years before the time of Christ. Aristotle sends a splendid, simple message down to us from long ago. "I found no basis prepared, no model to copy — mine is the first step and therefore a small one, though worked out with thought and hard labor. It must be looked at as a first step and judged with indulgence." Many years later Galen, who lived for some time in Rome, was one of the most brilliant scientists among all of the ancients. He was a man of originality who studied the lower animals very extensively.

Similarly we might come down through the ages to modern times. But it would be necessary to pause on the way if we were to speak with justice of all the great men who have made lasting contributions to the progress of science. In this book there are printed in connection with the subject most closely related to their work the names of a few of the great biologists who have contributed to human progress.

There are also included in this book the names of a considerable number of Americans who have played a large part in making the world a better place for us to live in — men like Darwin, Pasteur, Koch, Audubon, and Harvey. Distinguished American scientists living to-day probably outnumber those of any other nationality in the world. You should learn to respect these remarkable men who are doing so much to advance human progress.

OUTLINE

New discoveries
Improvements by breeding
Heredity
  Mendel
    His laws
Eugenics
  Defective families
    Jukes
    Kallikaks
  Strong families
    Bachs
    Edwards
    Darwins
Environment
Biology and progress

SUMMARY

Scientific progress, upon which so much of human progress depends, is due to scientific discoveries and the intelligent application of these discoveries to our lives. Domestic plants and animals have been greatly improved by experimental breeding. These improvements are based upon sound scientific principles. Heredity is the study of the similarity and differences that exist between parent and offspring. Owing to the method devised by Mendel, experts in the study of heredity can predict with a great deal of accuracy what characters will be inherited and in what proportion. The application of the principles of heredity to man are discussed under the term Eugenics.

QUESTIONS

What do you understand by Human Progress? How can Biology improve the conditions under which you live? Mention some of the ways in which it has improved them. How are new discoveries made? How can you make new discoveries? What does a scientific man do when he makes a new discovery? How does this differ from what a man does who makes an invention? How do we study heredity? Who was Mendel? What was his method? Why is it important to know about Eugenics? How can you help to improve the race?

RÉSUMÉ OF DEMONSTRATIONS FOR LABORATORY EXERCISES

Description of not less than 30 demonstrations should be recorded in the note-book of each student in the year course and not less than 15 demonstrations in the half-year course.

1. Demonstrations to observe the characteristics of some of the elements and compounds — oxygen, carbon, hydrogen, nitrogen, water, and carbon. Pages 24–27.

2. Demonstration of the physical appearance of each of some other elements and compounds — sulphur, phosphorus, iron, magnesium, sodium, potassium, sodium nitrate, calcium acid phosphate, and potash. Pages 26, 27.

The laboratory should have these substances.

3. Tests for the nutrients. Pages 42, 342, 344, 537.

4. Demonstration to show photosynthesis (includes necessity of light and of chlorophyll). Pages 39, 40, 461.

5. Demonstration to show digestion of food. (Use starch.) Pages 41, 42.

6. Demonstration to show osmosis. Pages 42, 43, 492.

7. Demonstration to show oxidation. Pages 40, 41.

8. Demonstration to show parts of protozoön studied. Pages 246, 247.

9. Demonstration to show effect of (*a*) alcohol, (*b*) tobacco on one-celled organisms. Page 252.

10. Demonstration, using manikin, models or organs of an animal, of important parts of the human body. Page 271.

11. Demonstration to show digestion of protein. Page 342.

12. Demonstration to show necessity of digestion of starch. Page 344.

13. Experiment to show normal rate of pulse and causes of variation. Pages 353, 354.

14. Demonstration to show growth with bacteria from different sources. Pages 392–396.

15. Microscopic demonstration of lower epidermis of leaf. Page 453.

16. Demonstration to show upward path of liquid through stem. Page 481.

17. Demonstration to show the region of root through which liquid rises. Pages 492, 493.

18. Demonstration to show position and kinds of food stored in seeds. Pages 537, 539. See also page 27.

19. Tests to show kinds and position of nutrients stored in seeds. Page 537.

20. Demonstration to show necessity of stored food in seed for germination and growth. Page 539.

21. Demonstration to prove necessity of air for germination. Page 539.

22. Demonstration to show production of carbon dioxide in germination. Pages 539, 540.

23. Demonstration to show necessity of moisture for germination. Page 540.

24. Demonstration to show necessity of moderate heat for germination. Page 540.

25. Demonstration to show the response of roots to (*a*) gravity, (*b*) moisture. Pages 493, 541.

26. Demonstration to show the response of stems to light. Page 541.

27. (Optional) Demonstration to show scales on the wing of moth or butterfly. Page 96.

28. (Optional) Demonstration of adaptations for stinging, carrying pollen, and cell building. Pages 100–102, 104–105.

29. (Optional) Microscopic demonstration to show blood corpuscles. Pages 349, 350.

30. (Optional) Demonstration to show the composition of bone. Pages 267, 268, 271.

31. (Optional) Demonstration to show the digestion of fat. Pages 338, 339, 342.

32. (Optional) Demonstration to show capillary circulation in web of frog's foot or organ of other animal. Pages 353, 356.

33. (Optional) Demonstration to illustrate action of human lungs and diaphragm in breathing. Pages 285–288.

34. (Optional) Demonstration to show liberation of gas from a water plant. Pages 462, 463.

35. (Optional) Demonstration to show circulation in warmed leaf of elodea. Page 441.

36. (Optional) Microscopic demonstration to show that plants are composed of cells. Page 440.

37. (Optional) Microscopic demonstration to show cellular nature of roots, root hairs, and root cap. Page 487.

38. (Optional) Demonstration to show the path of air to the lungs of a frog. Pages 143, 144, 152.

39. Demonstration of liberation of water vapor from leaves. Pages 462, 463.

NOTE. Demonstrations 27, 28, 29, 30, 31, 32, 33, 36, and 38 are optional only in the year course. They are required in a half-year course.

GLOSSARY

A

ABDO'MEN (Lat. *abdomen*, belly): the third region of an insect's body; the region below the chest in man.

ABSORP'TION (Lat. *absorbere*, to swallow down): the process of taking in liquid food or other substances through the walls of cells.

ACCES'SORY (Lat. *accedo*, give to) BUDS: more than the normal number (one) in the axil of a leaf. Accessory parts of a flower are the sepals and petals.

ACQUIRED IMMU'NITY: that which results from having had a disease, or from preventive measures.

ADAPTA'TION (Lat. *adaptere*, to fit): changes in, or peculiarities of organisms which make them fit for their environment; fitness.

AD'ENOIDS (Gk. *aden*, gland): fleshy growths in the cavity back of the nose.

ADUL'TERATE (Lat. *ad*, to, + *alter*, other): to add a cheap or inferior substance to a good one; to cheapen, weaken, or reduce.

ADVENTI'TIOUS (Lat. *ad*, to, + *venio*, come): appearing at unusual places, as roots on a slip.

AF'FERENT (Lat. *ad*, to, + *fero*, bear) FIBERS: those which convey stimuli to the sense organs, brain, or spinal cord.

AGGRES'SIVE (Lat. *ad*, to, + *gradior*, walk) COLORATION: that which protects an organism as it lies in wait for prey.

AKENE' (Gk. *a*, not, + *chainein*, to gape): a dry, indehiscent fruit, as in buttercup, dandelion, and clematis.

ALBU'MEN: a form of protein found in white of egg.

AL'COHOL: a narcotic poison; the intoxicating element in whisky, beer, wine, etc.

ALIMEN'TARY (Lat. *alimentum*, food) CANAL: the digestive tube or tract.

AL'KALINE SUBSTANCE: one which neutralizes an acid.

ALTRI'CIAL (Lat. *altrix*, nurse) BIRDS: those that are helpless when hatched, as robins, sparrows, etc.

Amphib'ians (Gk. *amphi*, double, + *bios*, life): animals that spend part of their life in water and part on land, as a frog.

Amphiox'us (Gk. *amphi*, double, + *oxys*, sharp): a small, burrowing, spindle-shaped marine animal; the ancestor of vertebrates.

Amylop'sin (Gk. *amylon*, starch): an enzyme found in the pancreatic juice that changes starch to sugar (glucose).

Anæsthet'ic (Gk. *an*, not, + *aisthesis*, feeling): substances that destroy consciousness.

An'giosperm (Gk. *angeion*, a case, + *sperma*, a seed): a plant which bears its seeds in a case, as pea, bean, poppy.

Annel'lida (Gk. *anulus*, ring): a group of worms composed of rings or segments, as earthworm.

An'nual (Lat. *annus*, year) ring: the concentric growths of light and dark cells formed in a woody stem during a year.

Anoph'eles: the kind of mosquito that carries the malarial parasite.

Anten'na (Lat. *antenna*, a sailyard): a jointed sensory organ on the heads of insects, crabs, etc.

Anter'ior (Lat. *ante*, before): nearer the head (zoöl.); facing outward from the axis (botany).

An'ther (Gk. *antheros*, flowery): the pollen-bearing part of a stamen.

Antisep'tic (Gk. *anti*, against, + *sepsis*, putrefaction): a substance which prevents the growth of bacteria or other organisms.

Antitox'in (Gk. *anti*, against, + *toxin*, a poison): a substance in the blood after certain diseases which confers immunity from further attacks for a greater or lesser period.

Anus (Lat. *anus*, ring): the posterior opening of the alimentary canal.

Aor'ta (Gk. *aorte*, from *aeirein*, to lift): the largest artery in the body; the one leaving the left ventricle.

Ap'iary (Lat. *apis*, bee): a place where bees are kept.

Appen'dage (Lat. *ad*, to, + *pendo*, hang): an organ, usually jointed, attached to the body.

A'queous (Lat. *aqua*, water) humor: the transparent liquid in the anterior part of the eye.

Arach'nida (Gk. *arachnē*, a spider): a class of arthropods which includes spiders, scorpions, mites, etc.

Ar'tery (Lat. *arteria*, an artery): a blood vessel that carries blood away from the heart.

Arthro'poda (Gk. *arthron*, joint, + *pod* (root of *pous*) foot): a group of animals having jointed legs, as insects.

Articula'tion (Lat. *articulo*, divide into joints): the joining or place of meeting of two bones.

ARTIFIC'IAL BREATHING (artificial respiration): that produced by mechanical means in an attempt to resuscitate drowned persons or those suffocated by gas.

ASEX'UAL: without sex; reproduction by other means than egg and sperm.

ASH: the grayish mineral substance resulting from the burning of organic matter, as wood.

ASSIMILA'TION (Lat. *assimulare*, to make like): the process of changing digested food into protoplasm.

ASTIG'MATISM (Gk. *a*, without, + *stigma*, spot): a defect in the curvature of the lens of the eye which causes indistinct vision.

AU'RICLES (Lat. *auricula*, little ear): the upper chambers of a vertebrate heart.

AX'ILLARY (Lat. *axilla*, dim. of *axis*, axis) BUDS: those which arise in the angle between the stem and the leaf.

B

BACIL'LUS (Lat. *bacillum*, little stick): a rod-shaped bacterium.

BACTER'IA (Gk. *bacteron*, a stick): the smallest and simplest plants.

BALANCED AQUARIUM: one in which plant and animal life supply each other's needs.

BALANCED DIET: one in which there are the correct amounts of carbohydrates, proteins, and fats.

BALL-AND-SOCKET JOINT: one in which the enlarged end of one bone fits into a depression in another, allowing free motion.

BAST: tough fibers in the inner bark of trees and other plants; part of the phloem.

BEETLE: an insect having hard wing covers; one of the Coleoptera.

BELLY OF MUSCLE: the middle portion.

BIEN'NIAL (Lat. *bi*, two, + *annus*, year): a plant which grows and stores food the first year and bears fruit the second year.

BILE: the fluid secreted by the liver.

BIOLOGICAL DISEASES: those caused by organisms.

BIOL'OGY (Gk. *bios*, life, + *logos*, a talk or discourse): the study of living things.

BI'VALVE (Lat. *bi*, two, + *valva*, leaf of a door): a mollusk having two valves or shells, as a clam.

BLADDER: the muscular sac in which urine collects.

BLADE: the expanded portion of a leaf.

BLAS'TULA (Gk. *blastos*, a bud): the hollow sphere stage in the development of certain eggs.

BLIGHT: disease of plants caused by certain fungi.

Body cavity: the space in which the vital organs are contained.

Bract (Lat. *bractea*, a thin metal plate): a small, leaf-like growth at the base of the pedicel of a flower.

Brain: the compact portion of the nervous system; in vertebrates, the part inclosed in the skull.

Bronchus, pl. *bronchi* (Gk. *bronchos*, windpipe): one of the two large subdivisions of the trachea.

Bud: an undeveloped branch or flower; an outgrowth on sponge, hydra, and yeast.

Budding: a form of grafting; the insertion of a bud of one tree under the bark of another.

Bulb: a cluster of thickened leaf-bases attached to a reduced stem, and surrounding a bud, as in onion, hyacinth, etc.

By-product: something produced incidentally in a manufacturing process, as oxygen in photosynthesis.

C

Cal'ōrie (Lat. *calere*, to be hot): a unit employed in estimating the kind and amount of food necessary to maintain the body at its best. It is the amount of heat required to raise one kilogram of water one degree Centigrade.

Cā'lyx (Greek, *kalyx*, cover): the outermost row of leaves or parts of a flower, usually green.

Cam'bium (Lat. *cambire*, to exchange): the active growing cells between the xylem and the phloem in the fibrovascular bundle of dicotyledonous plants.

Cap'illary (Lat. *capillus*, a hair): the microscopic blood vessels which fill the spaces between the ends of arteries and the beginnings of veins.

Căr'apace (Sp. *carapacho*, a covering): the shell-like dorsal covering of crustaceans and turtles.

Carbohy'drate (Lat. *carbo*, coal; Gk. *hydor*, water): the class of food stuffs made of carbon, hydrogen, and oxygen, the hydrogen and oxygen being in the same proportion as water.

Carbon diox'ide (Lat. *carbo*, coal; Gk. *di*, two; *oxys*, acid): a gas formed as a product of respiration and combustion.

Carniv'orous (Lat. *caro* (*carnis*), flesh; *vo'rare*, to eat): flesh-eating animals and plants.

Car'rier: a person who is immune to certain diseases the bacteria of which infest him, but capable of infecting others.

Căr'tilage (Lat. *cartilago*, gristle): the elastic animal tissue forming parts of organs or bones.

CĀ'SEIN (Lat. *caseus*, cheese): the form of protein found in the curd of milk.

CAT'ERPILLAR (Lat. *catta*, cat; *pilus*, hair): the active, larval stage in the metamorphosis of a lepidopterous insect; often covered with hair.

CAUD'AL (Lat. *cauda*, tail): pertaining to the tail.

CELL (Lat. *cella*, a small room): the unit of structure and function of living things. A mass of protoplasm inclosing a nucleus, and usually inclosed in a cell wall.

CELLULOSE (Lat. *cellula*, a little cell): an organic substance usually found in the walls of plant cells.

CEN'TIPEDE (Lat. *centum*, one hundred; Gk. *pod*, root of *pous*, foot): a small arthropod having two legs on each segment.

CERE (Lat. *cera*, wax): a fleshy growth at the base of the bill of some birds.

CEREBEL'LUM (Lat. *cerebellum*, little brain): the part of the brain behind the cerebrum in man, and overlying the midbrain.

CER'EBRUM (Lat. *cerebrum*, the brain): the anterior part of the brain.

CHAR'ACTER (Gk. *charakter*, an engraved mark or stamp): a trait or peculiarity passed on from parent to offspring. Characters may be *dominant*, or evident, or *recessive*, not showing for the generation or time being.

CHELA (Gk. *chele*, claw): the large pincers of a crayfish or lobster.

CHIROP'TERA (Gk. *cheir*, hand, + *pteron*, wing): the "hand-winged" mammals, as bats.

CHITIN (Gk. *chiton*, a gown or tunic): the outer covering of the bodies of some animals, as insects.

CHLOR'OPHYLL (Gk. *chloros*, green, + *phyllos*, leaf): the green coloring matter characteristic of plants; the substance which enables them to perform photosynthesis.

CHLOR'OPLAST (Gk. *chloros*, green, + *plastos*, molded): the granules in the protoplasm of a cell which contain chlorophyll.

CHRYS'ALIS (Gk. *chrysos*, gold): the quiescent stage in the development of a moth or butterfly; the pupa inclosed in a thin, smooth case.

CIL'IUM (Lat. *cilium*, an eyelid with eyelashes): a tiny hair-like projection of protoplasm attached to some portion of the surface of a cell.

CLAV'ICLE (Lat. *clavicula*, a little key): the collar bone, so named from its shape.

CLEISTOG'AMOUS (Gk. *kleistos*, closed, + *gamos*, marriage) FLOWERS: those which appear usually below the surface and are specially modified for self-fertilization. Violets produce cleistogamous flowers after the others.

Cloa'ca (Lat. *cloaca*, sewer): the lower end of the digestive tract which receives also wastes from the kidneys and the reproductive products in some vertebrates, as frogs and birds; the central cavity of a sponge.

Coal: a substance used for fuel, consisting largely of carbon formed from the remains of ancient vegetation.

Coc'cus (Gk. *kokkus*, berry): a spherical bacterium.

Cocoon' (Lat. *concha*, shell): the hairy or silken covering of the pupa of some insects; the egg case of spiders and earthworms.

Coe'lom (Gk. *koilos*, hollow): the body cavity; the part of the body in which the organs lie.

Coleop'tera (Gk. *coleos*, sheath, + *pteron*, wing): an order of insects having hard wing covers over the flying or true wings; the beetles.

Commu'nicable (Lat. *communico*, hold in common) diseases: those which can be given by one person to another. True of certain biological diseases, as diphtheria.

Compound' eyes (Lat. *compono*, put together): an eye made up of many separate facets or parts, as in insects and crayfish.

Conjuga'tion (Lat. *con*, with, + *jugare*, to join): the temporary union of two similar cells for the purpose of exchanging nuclear protoplasm, as in paramecium.

Conserva'tion of energy: Energy can neither be created nor destroyed. Any given amount may be made to assume different forms, as heat, light, motion.

Conserva'tion of matter: Matter can neither be created nor destroyed. Its form may be changed, as water which may exist as a gas, a liquid, or a solid; wood may be burned, or changed into water, smoke, and ashes.

Contract'ile vac'uole: a cell organ found in many Protozoa, which appears and disappears regularly.

Corm (Gk. *kormos*, tree trunk): a solid, underground stem for storage of food, as Jack-in-the-pulpit.

Corol'la (Lat. *corolla*, crown): the petals of a flower taken as a whole.

Cor'puscle (Lat. *corpusculum*, a little body): the floating cells in the blood, red and white.

Cor'tex (Lat. *cortex*, bark): the fleshy portion of a root surrounding the central cylinder and covered by epidermis.

Cor'ymb (Gk. *korymbos*, top): a flat-topped or rounded (convex) flower cluster.

Cot'yledon (Gk. *kotyledon*, a socket): the seed leaves of a plant. Monocotyledonous plants have only one, dicotyledonous plants have two.

Cross-fertiliza'tion: the union of the nuclei of the egg of one individual and the sperm of another.

Cross-pollina'tion: the receiving of pollen from a different plant by the pistil.

Crusta'cea (Lat. *crusta*, a crust): a group of animals covered with a hard exoskeleton, as crayfish.

Cu'lex: the scientific name of a very common, non-disease-bearing mosquito.

Culture: a controlled growth of bacteria, fungi, or Protozoa, usually in a prepared nutrient medium. A pure culture contains only one kind of organism.

Cu'tin (Lat. *cutis*, skin): the transparent waxy covering of leaves.

Cy'toplasm (*kytos*, vessel, + *plasma*, anything formed): the form of protoplasm which makes up the main part of a cell. It incloses the nucleus, and is inclosed by the cell wall.

D

Decid'uous (Lat. *de*, down, + *cado*, fall) leaves: those which fall from the tree in autumn.

Decomposi'tion (Lat. *de*, from, + *cum* (com), together, + *ponere*, to place): the act of separating into constituent parts; decay or rotting.

Dehis'cent (Lat. *de*, from, + *hiscere*, to open): a term applied to fruits that open, as pod, capsule, etc.

Deliques'cent (Lat. *deliquescere*, to melt or dissolve): a term applied to trees the trunks of which subdivide repeatedly.

Demonstra'tion (Lat. *de*, fully, + *monstro*, show): an orderly sequence of events, repeated by some one who wishes to explain or illustrate certain facts to learners. In a demonstration, the facts are already known. In an experiment, they are not known.

Den'tine (Lat. *den(t)s*, a tooth): the inner portion of a tooth.

Deod'orizer (Lat. *de*, from, + *odor*, smell): a substance used to modify or disguise odors.

Dermis (Gk. *derma*, skin): the true skin, lying beneath the epidermis.

Di'aphragm (Gk. *diaphragma*, a partition wall): the sheet of muscle which separates the chest cavity from the abdominal.

Di'astase (Gk. *diastasis*, separation): the enzyme or ferment in plants which converts starch to grape sugar (glucose).

Di'cotyle'don (Gk. *di*, two, + *kotyledon*, a socket): a plant which bears seeds having two cotyledons, as bean.

Diges'tion (Lat. *digestio*, the dissolving of food): the process of preparing food for absorption.

Dip'tera (Gk. *di*, twice, + *pteron*, wing): an order of insects which has only two wings, as fly and mosquito.

Disc (Gk. *discus*, a disc) flowers: the central portion of certain "flowers" like the daisy or sunflower.

Disinfect'ant (Lat. *dis*, apart, + *inficio*, make): a substance used to destroy harmful bacteria.

Dominant (Lat. *dominare*, to rule) characters: those which are most conspicuous in the hybrid.

Dor'mancy (Lat. *dormio*, sleep): the state of quiescence characteristic of seeds before germination.

Dor'sal (Lat. *dorsum*, the back): pertaining to the back.

Drone: the male of bees and ants.

Dry farming: the raising of crops in semi-arid regions.

Dry fruits: not fleshy. Nuts, cereals, pods, etc.

Ductless glands: those which pour their secretions directly into the blood, as thymus and adrenal glands.

E

Ec'toderm (Gk. *ectos*, outside, + *derma*, skin): the outer layer of cells of animals.

Ec'toplasm (Gk. *ectos*, outside, + *plasma*, thing molded): the outside layer of unicellular organisms.

Edenta'ta (Lat. *e*, out, + *den(t)s*, tooth): a group of mammals which have no teeth.

Ef'ferent (Lat. *e*, out, + *fero*, bear) fibers: the fibers that carry impulses away from the brain, the motor fibers.

Egg: the female element in sexual reproduction; the ovum.

El'ement (Lat. *elementum*, first principle): a substance which cannot be further simplified by any known means; one of the simple substances which, combined with others, make up the objects around us, both organic and inorganic.

Em'bryo (Gk. *embryon*, an embryo): an organism in its early stages of development.

Embryol'ogy (Gk. *embryon*, an embryo, + *logos*, a talk or discourse): the study of the development of organisms.

Enam'el: the hard outer covering of the upper part of the teeth.

Encyst'ment (Gk. *en*, in, + *kystis*, a bladder): the act of being inclosed in a resistant covering; forming a cyst.

En'doderm (Gk. *endon*, within, + *derma*, skin): the inner layer of cells in sponge, hydra, or an embryo.

En'doplasm (Gk. *endon*, within, + *plasma*, substance): the inner portion of the protoplasm in a one-celled animal.

EN'DOSKEL'ETON (Gk. *endon*, within, + *skeleton*, a dried body): a skeleton within the body, as in man.

EN'DOSPERM (Gk. *endon*, within, + *sperma*, a seed): the food that is stored near the embryo, as in a grain of corn.

EN'ERGY (Gk. *energos*, at work): the power or ability to perform work.

EN'TOMOL'OGIST (Gk. *entomon*, insect, + *logos*, talk or discourse): a person who studies insects.

ENVIR'ONMENT (Fr. *environ*, around): the surroundings of an organism.

EN'ZYME (Gk. *en*, in, + *zyme*, leaven): a substance secreted by organisms and inducing chemical changes, as digestion and fermentation.

EPHEMER'IDA (Gk. *ephemeros*, for a day): an order of insects which live but a few hours.

EP'IDEM'IC (Gk. *epi*, upon, + *dēmos*, the people): a disease that is widespread, affecting many people at the same time.

EPIDER MIS (Gk. *epi*, upon, + *derma*, skin): the covering of the true skin; the outer layer.

EPIGLOT'TIS (Gk. *epi*, upon, + *glottis*, glottis): the lid which closes the opening into the trachea when anything is swallowed.

EROS'ION (Lat. *erodere*, to gnaw off): the wearing away of a substance, especially soil, by the action of the natural elements, as water.

ESSEN'TIAL PARTS (of a flower): the stamens and pistils, both of which are necessary in forming a seed.

EUGEN'ICS (Gk. *eugēnes*, well born): the study of heredity in its relation to the improvement of offspring.

EUSTA'CHIAN TUBES: the tubes which connect the middle ear with the throat. Named for *Eustachius*.

EVERGREENS: plants which retain their leaves for several years; the cone-bearing trees, in general.

EVOLU'TION (Lat. *e*, out, + *volvo*, roll): the development of complex forms from simple ones; organic descent; the theory that accounts for present forms of life by tracing them from simpler forms which existed in the past.

EXCRE'TION (Lat. *excretus*, separated out): the process of removing waste products from the protoplasm; the products so removed.

EXCUR'RENT (Lat. *ex*, out, + *currere*, to run) STEM: a stem which extends from base to tip without dividing, as spruce, cedar, etc.

EXHAL'ENT (Lat. *ex*, out, + *halo*, breathe) PORE: the central opening at the top of a sponge through which water is passed outward.

EX'OSKELETON (Gk. *ex*, out, + *skeleton*, a dried body): the outer, crustaceous or horny covering of animals such as crayfish and insects.

EXPER'IMENT (Lat. *experior*, try): a test under controlled condi-

tions for the purpose of discovering new facts, truths, or relations. In a real experiment, the result is not known beforehand to the person investigating.

Expira'tion (Lat. *ex*, out, + *spiro*, breathe): the process of emptying the lungs of air in breathing.

Exten'sors (Lat. *ex*, out, + *tendo*, stretch): the muscles which straighten an appendage at the joint, as arm.

F

Fangs: the organs through which spiders, snakes, and other animals inject poison or venom into their prey or enemies.

Fas'cicled (Lat. *fasciculus*, a little bundle) roots: the clustered, fleshy roots of dahlia and other plants.

Fatigue' (Lat. *fatigo*, tire): the effect of exertion or other stimulation of cells or organs.

Fats: one of the common classes of nutrients, containing much carbon and hydrogen and little oxygen.

Feathers: the characteristic covering of birds.

Fe'ces (Lat. *faeces*, dregs): the wastes from the alimentary canal; excrement.

Feelers: antennae; the long, slender, jointed projections from the head found chiefly in crustaceans.

Fehling's solution: a substance used to determine the presence of glucose or grape sugar. Several formulas are in common use.

Fe'mur: the long bone of the lower limb in vertebrates; the large portion of the leg of a grasshopper.

Fer'ment: an enzyme; a substance which produces fermentation.

Fertiliza'tion (Lat. *fertilis*, from *fero*, bear): the union of the sperm nucleus with the egg nucleus in forming a new individual or organism.

Fer'tilizer: a substance added to the soil to promote plant growth.

Fibrin'ogen (Fr. *fibre*, a fiber): the substance in the blood which induces clotting by the production of fibers when exposed to air.

Fi'brous (Fr. *fibre*, a fiber) roots: those composed of many slender fibers, as grass.

Fibrovas'cular bundles: the conductive system of plants. A fibrovascular bundle consists of xylem cells which communicate by means of perforations in the sides of their thick walls, and phloem cells which are thin-walled and perforated at the ends. Other cells, nonconductive, are found in or near the bundle.

Fil'ament (Lat. *filum*, thread): the slender stalk of a stamen; any thread-like projection.

FIN: a locomotor organ characteristic of fishes and used for locomotion, balancing, and steering.

FIS'SION (Lat. *findere*, to split): division into two smaller cells by a process of splitting or pinching in two.

FLAC'CID (Lat. *flaccus*, flabby): a soft or relaxed condition of a cell due usually to shortage of water.

FLAGEL'LUM (Lat. *flagellum*, a whip): a long protoplasmic projection, used chiefly for locomotion.

FLATFOOT: a common disease caused by the breaking down of one or more of the arches.

FLATWORMS: a group of unsegmented worm-like animals, many of which are parasitic, as liver fluke and tapeworm.

FLESHY FRUITS: those that have the seeds surrounded by an edible, juicy layer, as pome (apple), drupe (plum).

FLEX'ORS (Lat. *flexus* (*flecto*), bend): muscles that bend the joints; the set that work in opposition to *extensors*.

FLIPPER: the fore limb of a seal or other aquatic mammal, modified as a swimming organ.

FLOWER: the organ of a plant which produces fruit containing seeds; or one of the essential parts of such an organ, as staminate flowers of corn, pistillate flowers of willow.

FOOD: a substance that furnishes material for the growth or repair of an organism, or that yields energy for it.

FORESTRY: the study and practice of producing successive crops of trees from a given tract.

FOSSILS: the stone-like remains of plants and animals no longer living on the earth.

FRUIT: the ripened ovary and its contents. In some fruits traces of parts of the flower may be seen adhering to them.

FRY: young fishes just able to take care of themselves.

FUNC'TION (Lat. *functio*, performance): the normal action of any organ or set of organs; use.

FUNDAMENT'AL FUNC'TIONS: those on which an organism depends for existence, as respiration, excretion, etc.

FUN'GUS (Lat. *fungus*, mushroom): a plant which lacks chlorophyll. Fungi are dependent on prepared (organic) food, dead or alive.

G

GALL: (Lat. *galla*, gallnut): a growth produced on certain leaves by the action of insects; the bile.

GALL BLADDER: the sac in which gall or bile is stored temporarily.

GAN'GLION (Gk. *ganglion*, tumor): a collection of nerve cells.

Gas: one of the forms in which matter exists, as oxygen, hydrogen.

Gas'tric (Gk. *gaster*, stomach): pertaining to the stomach, as gastric glands.

Gas'trula (Gk. *gaster*, stomach): the two-layered stage in the development of an egg into an embryo.

Genera'tion (Lat. *generatus*, from *genero*, beget): the persons existing at one time or period. Applied also to plants and animals.

Gen'us (Lat. *genero*, beget): a group of organisms including one or more species. Used in classifying plants and animals.

Germ (Lat. *germen*, sprig): a microörganism; the rudimentary vital element; an embryo.

Germina'tion (Lat. *germinatus*, from *germino*, sprout): the beginning of growth of a seed or pollen. This is commonly used to describe the growth of a plant from a seed. It more properly describes the growth of the embryo within the seed.

Gill rakers: projections on the gill arches of some fishes to assist in gathering food.

Gill slits: openings in the neck through which water, taken into the mouth, passes out over the gills, as in fishes.

Gills: thin, finely divided organs of aquatic vertebrates, used to gather oxygen.

Gir'dle: the bones which attach vertebrate limbs to the axial skeleton. The anterior is called the *pectoral* and the posterior the *pelvic* girdle; to encircle with a deep cut or by removing the bark, as to girdle a tree.

Giz'zard (Lat. *gigeria*, cooked entrails of poultry): the muscular chamber where food is ground. A characteristic organ of birds.

Gland: an organ which produces a substance for use in the body, or for removal from it; examples, salivary gland, kidney.

Glomer'ulus (Lat. *glomero*, make a ball): minute rounded bodies in the cortex of a kidney; a knot of blood vessels; a Malpighian body.

Glot'tis (Gk. *glōtta*, tongue): the opening into the trachea.

Glu'cose (Gk. *glykys*, sweet): the form of sugar found in fruits; the product of the digestion of starch.

Glu'ten (Lat. *gluten*, glue): the proteid substance in cereals which makes them sticky when wet and crushed.

Gly'cerin (Gk. *glykeros*, sweet, from *glykys*): the sweet substance resulting from the digestion of natural fats.

Gly'cogen (Gk. *glykys*, sweet, + *gen*, producing): animal starch, stored in the liver.

Gon'ad: an undeveloped sex organ, or one which cannot be recognized as either male or female in the non-reproductive season.

GON'IUM: a very small animal which consists of a colonial group of eight cells, each practically independent.

GRAFT'ING: the process of inserting a small piece (twig) of one plant (the scion) into a slit in a larger one (the stock) and protecting it till the parts grow together.

GRAIN (Lat. *granum*, grain): one of the cereals, or cereals in general; a kernel of corn; the markings on wood due to annual rings and medullary (wood) rays.

GRAV'EL: small stones or pebbles, usually rounded and often mixed with sand.

GRAV'ITY (Lat. *gravis*, heavy): the force which tends to draw objects towards the center of the earth.

GREEN GLANDS: excretory organs of a crayfish, found in the head region.

GREEN MANURING: the process of plowing under a crop of some leguminous plant, as clover, for the sake of the nitrogen which has been gathered by bacteria living on its roots.

GRUB: the larva of certain beetles, as white grub, the larva of the May beetle.

H

HAB'IT (Lat. *habitus*, condition): a tendency towards an action or condition which, by repetition, has become spontaneous.

HAB'ITAT (Lat. *habito*, inhabit): the region where any organism or group of organisms is usually found; the place where it lives.

HÆMOGLO'BIN (Gk. *haima*, blood, + Lat. *globus*, globe): the red coloring matter in the small blood corpuscles.

HÆ'MORRHAGE (Gk. *haima*, blood, + *rhegnymi*, break): the discharge of blood from a ruptured blood vessel.

HARD PAL'ATE: the bony part of the roof of the mouth.

HEAD: the division of the body which contains the brain; a collection of small flowers; the collection of grains which make up the fruit of cereals.

HEALTH: the condition resulting from the normal performance of all the life functions.

HEMIP'TERA (Gk. *hemi*, half, + *pteron*, wing): an order of insects which has the anterior part of its wings hard and the posterior part membranous.

HERBIV'OROUS (Lat. *herba*, grass, + *voro*, eat): animals which feed upon grass and other plants.

HERED'ITY (Lat. *heres*, heir): the passing on to offspring of characters of parents or other ancestors.

Hiberna'tion (Lat. *hiems*, winter): the condition induced by severe cold in the case of some animals; a death-like torpor and rigidity brought about by extreme cold.

Hi'lum: the scar on a seed showing where it was attached to the fruit.

Hinge joint: one which admits only of back-and-forth motion, as the elbow.

Homop'tera (Gk. *homos*, same, + *pteron*, wing): a group of insects having their wings of the same texture throughout, in contrast to other Hemiptera.

Hon'ey: the partly digested food of bees. They suck up nectar which is retained in the crop till partially digested, after which it is pumped up and stored in cells of wax.

Hook'worm: a small parasitic, unsegmented, round worm found in the intestine of man, sheep, and other animals.

Hor'mones (Gk. *hormaein*, to excite): substances secreted directly into the blood in one part of the body which are carried by the circulation and incite action in another part of the body; chemical messengers.

Host (Lat. *hospes*, entertainer): the larger organism on or in which a smaller, dependent one (parasite) lives.

Hu'merus (Lat. *humerus*, shoulder): the larger bone of the upper arm.

Hu'mor (Lat. *humere*, to be moist): the transparent liquids of the eyeball.

Hu'mus (Lat. *humus*, ground): the substances in the soil formed by the decay of organic matter; vegetable mold.

Hy'brid (Lat. *hybrida*, mongrel): the offspring of parents of two different species or varieties. The mule is a hybrid.

Hy'dra (Gk. *hydōr*, water): a two-layered aquatic animal; a polyp.

Hy'drogen (Gk. *hydōr*, water, + *gen*, create): one of the two elements that enter into water; the lightest known substance.

Hy'giene (Gk. *hygeia*, health): the study of health, especially as to maintaining health by observing proper conditions.

Hymenop'tera (Gk. *hymen*, a membrane, + *pteron*, wing): an order of insects (including bees and wasps) which have membranous wings.

Hy'phæ (Gk. *hyphai*, a web): the single strands or threads which make up the body of a fungus.

Hy'pocot'yl (Gk. *hypo*, under, + *kotyledon*, socket): the part of a developing plant embryo which lies between the stem and the root.

Hypophar'ynx (Gk. *hypo*, under, + *pharynx*, throat): the tongue-like organ of a grasshopper.

I

ICHNEU'MON (Gk. *ichneuō*, hunt): a hymenopterous insect which lays its eggs on the larvae of other insects or in them; a helpful parasitic insect.

IMBECIL'ITY (Lat. *imbecillus*, weak): the state or condition of being far below normal in mental development; feeble-mindedness.

IMMU'NITY (Lat. *immunis*, free from duty): the condition which prevents a person from "taking" an infectious disease.

INCIS'OR (Lat. *incido*, cut into): a cutting tooth. In gnawing animals the incisors have chisel edges.

IN'CURRENT (Lat. *in*, in, + *curro*, run) SIPHON: the tube through which water enters the gill chamber of clams.

INDEF'INITE ANNUAL GROWTH: the forming of new wood throughout the whole growing season, as in sumac.

INDEHIS'CENT (Lat. *in*, not, + *dehiscere*, to open) FRUITS: those that do not open, as nut, grain of corn, akene.

INDETER'MINATE (Lat. *in*, not, + *de*, completely, + *termino*, terminate) IN FLORES'CENCE (Lat. *in*, in, + *floreo*, bloom): a form of flowering in which the axis continues to grow and new flowers continue to form. A plantain illustrates it.

INFUS'ION (Lat. *in*, in, + *fusus*, from *fundo*, pour): the process of steeping a substance in a liquid for the purpose of extracting its medicinal or other qualities; the liquid extract so obtained, as hay infusion.

IN'HALENT (Lat. *in*, in, + *halo*, breathe) PORES: the mouths of tubes which conduct water inward through the walls of a simple sponge.

INOCULA'TION: the introduction of a virus, as of smallpox, into the system through the skin.

INORGAN'IC (Lat. *in*, not, + *organum*, organ) MATTER: that which has not been formed by living (organic) processes.

IN'SECT (Lat. *in*, in, + *sectum*, cut): a group of small animals having three distinctly marked-off body regions.

INSECTIV'ORA (Lat. *insectum*, insect, + *voro*, to eat): an order of insect-eating vertebrates, including moles and shrews.

INSER'TION (Lat. *insertus*, from *in*, in, + *sero*, join): the place of attachment of a muscle.

INSPIRA'TION (Lat. *in*, in, + *spiro*, breathe): the act of taking air into the lungs.

IN'SULIN: a newly discovered remedy for the treatment of diabetes.

INTEG'UMENT (Lat. *in*, in, + *tego*, cover): an outer covering or envelop, as the skin.

INTES'TINE (Lat. *intestinus*, internal): that portion of the alimen-

tary canal in vertebrates between the stomach and the anus. There are two divisions or sections, the small intestine and the large intestine.

INVERT'EBRATES (Lat. *in*, not, + *vertere*, to turn): all animals which lack a vertebral column, as worms, insects, mollusks.

INVOL'UNTARY (Lat. *in*, not, + *voluntas*, from *volo*, will) MUSCLES: those which are not under the control of the will, as the muscles of the intestine.

I'ODINE (iodin): one of the elements. It is used as a test for the presence of starch which it turns blue, also as an antiseptic and a preventive of goiter.

I'RIS (Gk. *iris*, rainbow): the colored portion of the eye.

IRRITABIL'ITY (Lat. *irritabilis*, from *irrito*, excite): the property of reacting to stimuli; a life function.

J

JELLYFISH: a soft, jelly-like animal related to hydra.

JOINT (Lat. *jungo*, join): the place where two bones meet; an articulation.

K

KEEL: the projection on the breastbone of birds for the attachment of muscles for moving the wings.

KID'NEY: a gland which secretes urine.

KINET'IC (Gk. *kinein*, to move) ENERGY: that form of energy employed in producing motion.

L

LA'BIUM (Lat. *labium*, lip): the lower "lip" of a grasshopper's mouth.

LA'BRUM (Lat. *labrum*, lip): the upper "lip" of a grasshopper's mouth.

LAC'TEALS (Lat. *lac*, milk): the vessels which carry the absorbed food from the intestine to the vein which receives it.

LAR'VA (Lat. *larva*, a ghost): the eating and growing stage in the complete metamorphosis of some insects, as moths and butterflies.

LAR'YNX (Gk. *larynx*, gullet): the portion of the trachea which contains the vocal cords; the voice box; "Adam's apple."

LA'TENT (Lat. *lateo*, lie hidden) ENERGY: that form of energy which, temporarily, is not at work, as a tightly wound watch spring.

LAT'ERAL (Lat. *latus*, side) BUD: one which is on the side of a stem.

LAY'ERING: the covering of the nodes of a stem with dirt to induce it to produce roots; a means of propagating such plants as grape vines.

LEAF MOSA'IC: the arrangement of leaves to cover all spaces, as ivy on a wall.

LEATH'ER (A.-S. *lether*, leather): the skin of an animal when tanned or otherwise prepared for use.

LEGUMES' (Lat. *legere*, to gather): plants which have pods for fruits; the seeds of such plants, as peas, beans, etc.

LEGU'MIN: the proteid substance found in seeds of the pulse (pea) family.

LEN'TICEL: an opening in bark for the admission of air.

LEP'IDOP'TERA (Gk. *lepis*, scale, + *pteron*, wing): the order of insects characterized by having scaly wings, as moths and butterflies.

LIFE CYCLE: the stages of development, maturity, and decline through which every organism passes.

LIFE FUNCTIONS: the various physical processes upon which the continuance of life depends; the vital processes, as digestion, respiration, etc.

LIG'AMENT (Lat. *ligare*, to bind): a band of tissue which binds one bone to another.

LIP'OID (Gk. *lipos*, fat, + *eikos*, like): a substance found in abundance in cells of the nervous system which is dissolved by anæsthetics and narcotics.

LIQ'UID (Lat. *liquere*, to be fluid): a form of matter in which the particles move easily upon one another, as water, and take the shape of the container.

LIV'ER: the largest organ of the body, a gland which secrets bile, stores glycogen, and performs other functions.

LOAM: a form of soil containing much humus (which see).

LOCOMO'TION (Lat. *locus*, place, + *motus*, fr. *moveo*, move): moving from one place to another. In many animals locomotion is essential in food-getting.

LYMPH (Lat. *lympha*, clear water): the fluid resembling plasma which fills intercellular spaces. The watery substance in a blister is lymph.

LYMPHAT'IC (Lat. *lympha*, clear water): a vessel that conveys lymph; pertaining to lymph.

M

MAGGOT: the legless larva of a fly.

MAGNES'IUM: one of the elements a trace of which is found in protoplasm.

MALA'RIA (Lat. *malus*, bad, + *aër*, air): a biological disease caused by parasitic protozoöns which live in the body of the mosquito known as Anopheles during part of their life history, and part in the blood of man to which they are transmitted by the bite of a mosquito. Malaria was once thought to be due to breathing bad air, especially night air.

MALES: individuals producing sperms.

MAM'MARY (Lat. *mamma*, breast) GLANDS: the milk-secreting glands which are characteristic of mammals.

MAN'DIBLE (Lat. *mandere*, to chew): the cutting part of the mouths of crustaceans.

MARSU'PIALS (Gk. *marsipion*, a little pouch): an order of mammals having a pouch in which the young are carried, as opossum, kangaroo.

MAXIL'LA (Lat. *maxilla*, jaw): one of the mouth-parts of crustaceans.

MAXIL'LIPED (Lat. *maxilla*, jaw, + *pes*, foot): an appendage near the mouth of a crustacean which assists in getting or passing food.

MEAS'URING WORMS: the larvae of certain moths which move by looping their bodies.

MEDUL'LA (Lat. *medius*, middle) OBLONGATA: the posterior part of the brain, connecting it with the spinal cord.

MED'ULLARY (Lat. *medulla*, pith) RAYS: thin bundles of wood cells extending from the meristem to or towards the center; wood rays.

MEN'DELISM: a law of heredity first announced or discovered by Gregor Mendel.

MER'ISTEM (Gk. *meristos*, divisible): the actively growing tissue found in the tips of roots and stems.

MES'ENTERY (Gk. *mesos*, middle, + *enteron*, intestine): a fold of tissue which suspends the intestine from the dorsal wall of the abdomen.

MESOGLE'A (Gk. *mesos*, middle, + *glorios*, glutinous substance): the middle, non-cellular layer of hydra.

MES'OPHYLL (Gk. *mesos*, middle, + *phyllon*, leaf): the middle portion of a leaf, consisting of irregular, loosely packed cells.

MESOTHO'RAX (Gk. *mesos*, middle, + *thorax*, thorax): the middle section of the thorax of an insect. It has one pair of wings and the second pair of legs on it.

METAMOR'PHOSIS (Gk. *meta*, beyond, + *morphé*, form): a life history in which the organism passes through several changes of form, as butterfly, frog.

METATHO'RAX (Gk. *meta*, beyond, + *thorax*, thorax): the third division of an insect's thorax. It bears the last pair of legs, and the second pair of wings, if any.

MI'CROBE (Gk. *mikros*, small, + *bios*, life): a microscopic organism; a bacterium.

MI'CROPYLE (Gk. *mikros*, small, + *pyle*, gate): the opening in the testa of an ovule through which the pollen tube enters.

MID'RIB: the main vein or rib of a leaf.

MIGRA'TION (Lat. *migro*, move): the act of changing a dwelling place from one locality to another, as birds, salmon.

MIL'DEW: a fungus which causes decay and disease.

MILT: the sperms of a fish.

MIM'ICRY (Gk. *mimikos*, imitative): resemblances in form or color which some organisms show to other objects, to protect them.

MIX'TURE (Lat. *miscio*, mix): a combination of several ingredients in which each retains its own individuality.

MOL'ECULE (Lat. dim. of *moles*, mass): the smallest part of a substance that can exist without losing its identity.

MOL'LUSKS (Lat. *mollis*, soft): a group of animals having soft bodies, usually covered by one or two shells.

MOLT: to cast off, as skin in snakes, feathers in birds, skin in larvae.

MONOCOT'YLEDON (Gk. *monos*, single, + *kotyledon*, socket): a plant which has only one cotyledon, in its seeds, as corn.

MOSA'IC VISION: the image formed by the compound eye of an insect, each facet producing a part which fits in with others to make a complete picture.

MOTHS: insects resembling butterflies; small lepidopterous insects which infest wool, cloth, fur, etc.

MOTOR (Lat. *moveo*, move) FIBERS: nerve fibers which convey impulses from the brain to the muscles, producing motion.

MOVABLE JOINTS: those capable of motion; opposed to sutures, which are immovable joints.

MU'COUS (Lat. *mucus*, slime) MEMBRANE: the lining of the alimentary canal and respiratory tract.

MUCUS (Lat. *mucus*, slime): a slimy substance secreted by certain cells of the mucous membrane.

MULE (Lat. *mulus*, mule): the offspring of a horse and a donkey.

MUS'CLE: an organ made up of contractile fibers, the function of which is to produce motion.

MUSH'ROOM: a fleshy fungus, particularly the edible field mushroom with pink gills.

MYCEL'IUM (Gk. *mycēs*, mushroom): the (hyphal) threads which make up the body of a fungus.

MY'OSIN (Gk. *myo*, muscle): the form of protein which exists in muscle.

MYRIOP'ODA (Gk. *myrioi*, ten thousand, + *pous*, foot): a group of crustaceans having four legs on each segment.

N

NARCOT'IC (Gk. *narkotikos*, making numb): a substance which dissolves lipoid, dulls the senses, and in sufficient quantity produces insensibility.

NAT'URAL IMMU'NITY: the state of not being liable to "take" an infectious disease.

NAT'URAL SELEC'TION: the survival of those organisms which are best adapted to live under certain conditions, and the perishing of those less well adapted.

NEC'TAR (Gk. *nectar*, drink of the gods): the sweet fluid secreted by nectar glands in a flower; the substance from which bees make honey.

NERVE FIBERS: the separate fibers of which a nerve is made up; the elongated processes of neurons (nerve cells).

NERVOUS SYSTEM: the system by means of which an animal becomes aware of its surroundings, and by which it adjusts itself to them; the coördinating system.

NET-VEINED LEAF: one in which the veins branch again and again, forming a network.

NIC'TITATING (Lat. *nictare*, to wink) MEMBRANE: a thin, almost transparent inner eyelid found in certain vertebrates, as frog, bird, cat.

NISSL BODIES: granules in the bodies of nerve cells which disappear when the cell has been subject to frequent and prolonged stimulation.

NI'TROGEN: one of the elements in the form of gas. Besides constituting about four fifths of the air, it is found in many organic substances, as protein.

NODE (Lat. *nodus*, knot): the places on a stem from which branches arise in dicotyledons, and leaves in monocotyledons.

NO'TOCHORD (Gk. *notos*, the back, + *chordé*, a string): a rod in the back of the embryos of vertebrates around which the spinal column develops.

NOUR'ISHMENT (Lat. *nutrio*, nurse or feed): that which sustains, or promotes growth in any way.

NUCELL'US (dim. of *nux*, nut): the tissue which fills the space not occupied by the embryo sac in an ovule.

NU'CLEUS (Lat. *nucleus*, a kernel): the center of vital activity in a cell; specialized protoplasm, part of which transmits heritable traits to offspring.

NUT: a dry, indehiscent fruit with a hard pericarp, as walnut, hazel nut.

NU'TRIENTS (Lat. *nutrio*, nurse or feed): foods, such as starches, sugars, proteins, edible fats, and mineral matter, which contain the necessary elements for keeping the body in repair and making it grow; food compounds.

NUTRI'TION (Lat. *nutrio*, nurse or feed): the process by which growth is promoted and repairs made in living organisms.

NYMPH: an immature form of an insect, as grasshopper, which has incomplete metamorphosis.

O

ODONA'TA (Gk. *odontos*, toothed): an order of insects including dragon flies and damsel flies.

ŒSOPH'AGUS (Esophagus) (Gk. *oisō*, will bear, + *phagein*, to eat): the tube through which the food passes from the pharynx to the stomach; the gullet.

OIL: (Lat. *oleum*, oil): a liquid substance of organic origin, containing carbon, hydrogen, and oxygen, insoluble in water. A food substance (edible fat).

OLFAC'TORY (Lat. *oleo*, smell, + *facio*, make) NERVE: the nerve which supplies the organ of smell.

OPER'CULUM (Lat. *operculum*, lid): the gill cover in fishes.

OPTIC (Gk. *optikos*, sight) NERVE: the nerve which conducts stimuli from the retina to the brain.

OR'DER (Lat. *ordo*, order): in classification, a group of organisms made up of several similar families.

OR'GAN (Gk. *organon*, instrument): any part of a plant or animal which performs some definite function.

ORGAN'IC ASH: the mineral matter left after the complete burning of plant or animal substances.

ORGAN'IC SUBSTANCE: any substance made by plants or animals.

OR'GANISM (Gk. *organon*, instrument): a plant or an animal; a body composed of different organs performing special functions that are mutually dependent and essential to life.

OR'IGIN (Lat. *orior*, rise): the attachment of a muscle nearest the center of the body.

ORTHOP'TERA (Gk. *orthos*, straight, + *pteron*, wing): a group of insects whose outer wings meet in a straight line in the middle of the back. It includes grasshoppers and crickets.

OSMO'SIS (Gk. *ōsmos*, pushing): the passing of soluble substances through a moist membrane, the greater movement being towards the denser liquid.

O'VARY (Lat. *ovum*, an egg): the organ in female animals and in plants which produces ova or eggs.

O'VIDUCT (Lat. *ovum*, egg, + *duco*, lead): the tube through which the eggs leave the body.

O'VIPOS'ITOR (Lat. *ovum*, egg, + *pono*, place): the organ in insects by which eggs are thrust into a hard substance, as earth or wood.

O'VULE (Lat. *ovulum*, a little egg): the body, in plants, which con-

tains the egg cell. In case the egg cell is fertilized, the ovule develops into a seed or a fruit, as a grain of corn.

Ov'um (Lat. *ovum*, egg): the sexual element produced by the female.

Oxida'tion: the chemical union of oxygen with another substance.

Ox'ygen: a gas, one of the elements. It is very abundant in nature, existing in the air as O_2 and in combination with carbon and hydrogen and nitrogen to make sugars, starches, and protein.

P

Pal'ate (Lat. *palatum*, palate): the roof of the mouth.

Palisade' cells: a row of cells longer than wide lying just beneath the epidermis of leaves.

Palmately compound leaves: those in which the leaflets, five or more in number, arise from the top of the petiole.

Palp (Lat. *palpo*, stroke): one of the sensory, jointed mouth parts of crayfish, insects, etc.

Pan'creas (Gk. *pas*, all, + *creas*, flesh): a gland which secretes a liquid containing enzymes used in the intestinal digestion of food.

Papil'la: a small projection, as from the surface of the tongue.

Pap'pus (Gk. *pappos*, down): the tuft of down on the fruits of certain plants, as thistle, dandelion, for distribution by wind.

Parallel venation: the characteristic venation of monocotyledonous plants in which a number of veins of about the same size run side by side from base to apex of the leaf.

Par'asite (Gk. *para*, beside, + *sitos*, food): a small, dependent organism which gets its food directly from a larger one, the host, without any benefit to the latter.

Pasteuriza'tion (named from Pasteur, the originator): the process of killing most of the harmful bacteria in milk by heating it for a short time and cooling it quickly.

Peat: a substance composed of partially carbonized organic matter, chiefly plants, found in bogs, and used for fuel when dry.

Pec'toral (Lat. *pectus*, breast) girdle: the bones which support the anterior limbs of vertebrates and attach them to the trunk.

Pedun'cle (Lat. *pedunculus*, little foot): the axis or stem to which the several flowers of an inflorescence are attached, as in lily-of-the-valley.

Peg of hypocot'yl: the hard portion on the top of the arch of the hypocotyl which protects it from injury and assists it in piercing the soil.

Pel'vic (Lat. *pelvis*, basin) girdle: the bones to which the posterior limbs of vertebrates are attached.

PEL'VIS (Lat. *pelvis*, basin): the broad, curved bones which support the organs of the abdomen.

PEP'SIN (Gk. *pepsis*, cooking): the ferment in the gastric juice which acts on protein.

PEP'TONE: the substance resulting from the digestion of protein by pepsin.

PEREN'NIAL (Lat. *per*, through, + *annus*, year): a plant which lives year after year, as a tree.

PERFECT FLOWER: one which has both stamens and pistil, the essential organs.

PE'RIANTH (Gk. *peri*, around, + *anthos*, flower): the sepals and petals of a flower taken together when they are similar in shape and color, as in a lily.

PERICAR'DIUM (Gk. *peri*, around, + *cardia*, heart): the membranous sac surrounding and inclosing the heart.

PERIOS'TEUM (Gk. *peri*, around, + *osteon*, bone): the membrane which covers bones and adheres to them.

PERISTAL'SIS (Gk. *peri*, around, + *stalsis*, constriction): the squirming motion in the intestine caused by the contraction and relaxation of its muscles.

PERSPIRA'TION (Lat. *per*, through, + *spiro*, breathe): the watery secretion of the perspiratory glands; the substance secreted.

PET'AL (Gk. *petalon*, leaf): one of the colored parts which make up the corolla of a flower.

PET'IOLE (Lat. *petiolus*, fruit stalk): the part of a leaf by which it is attached to the stem; the leaf stalk.

PHA'GOCYTES (Gk. *phagein*, to eat, + *cytos*, sac): the white corpuscles of the blood which act as scavengers.

PHAR'YNX (Gk. *pharynx*, gullet): the cavity back of the mouth common to the respiratory and digestive systems.

PHLO'EM (Gk. *phloios*, inner bark): the outer part of a fibrovascular bundle in a dicotyledonous plant.

PHOS'PHORUS (Gk. *phōs*, light, + *phero*, bear): one of the elements found in minute quantities in protein.

PHOTOSYN'THESIS (Gk. *phos*, light, + *synthesis*, putting together): the process of making starch, peculiar to green plants.

PHYSIOLOGICAL OXIDATION: a slow combustion without flame or smoke, but with the production of heat and the formation of carbon dioxide and water. It takes place constantly in all active organisms.

PHYSIOL'OGY (Gk. *physis*, nature, + *logos*, a talk): the study of the life processes of organisms.

PISTIL (Lat. *pistillum*, from *pinso*, pound): the central part of a flower consisting of a stigma, style, and ovary (which see).

PITH: the soft, spongy tissue in the center of a woody stem; the substance between the vascular bundles in a monocotyledonous stem.

PLACEN'TA (Lat. *placenta*, cake): the tissue to which seeds are attached in the ovary of a plant.

PLAS'MA (Gk. *plasma*, a thing formed): the liquid portion of the blood of vertebrates.

PLECOP'TERA (Gk. *plectos*, plaited, + *pteron*, wing): an order of insects having plaited wings, as stone flies.

PLU'MULE (Lat. *plumula*, little feather): the first bud of an embryo plant.

POD: the seed case of certain plants, as pea; a form of dry, dehiscent fruit.

POI'SON (Lat. *potio(n)* from *poto*, drink): any substance which acts in a harmful manner when taken into the system of an organism.

POL'LEN (Lat. *pollen*, fine flour): the fine, powdery substance formed in the stamens of flowers. Each grain contains a sperm nucleus for fertilizing the egg cell in an ovule.

POL'LINA'TION (Lat. *pollen*, fine flour): the act of receiving pollen on the stigma of a pistil.

POME (Lat. *pomum*, fruit): a fruit having thick, fleshy walls which inclose the papery pod containing the seeds, as apple, pear, quince.

POR'TAL (Lat. *porta*, gate) VEIN: the large vein that carries blood to the liver.

POSTER'IOR (Lat. *posterus*, following) PART: the hinder portion of an organism.

POTAS'SIUM: one of the elements found in minute quantities in protoplasm.

POTEN'TIAL (Lat. *potentia*, power) ENERGY: that which is temporarily inactive, as that in a tight spring.

PRAECO'CIAL (Lat. *prae*, before, + *coquere*, ripen): birds which are able to run soon after hatching.

PRESER'VATIVE (Lat. *prae*, before, + *servo*, save): a substance added to food to prevent its "spoiling." Sugar in fruit, salt or smoke on meat are examples.

PRESERVE' (Lat. *prae*, before, + *servo*, save): a place in which plants or animals, or both, may not be molested.

PRI'MARY (Lat. *primus*, first) FOODS: all plant foods, and such animal foods as fish and oysters, where the animal gets its nourishment from some other source than primary foods and fodders.

Pri'mary (Lat. *primus*, first) root: the first and usually the main root of a plant; the tap root.

Pri'mates (Lat. *primus*, first): a group of animals which stand at the head in intelligence, as monkeys, apes, etc. Man, as an animal, is a Primate.

Proboscid'ia (Gk. *pro*, before, + *boskō*, feed): a group of animals characterized by having a proboscis.

Probos'cis (Gk. *pro*, before, + *boskō*, feed): an elongated appendage for gathering food. In insects, a coiled tube; in elephants, a prehensile nose and upper lip.

Protec'tive coloration: coloration which fits in with the environment, as toad, frog, grasshopper, tree frog.

Protec'tive resem'blance: the resemblance of a harmless organism to a harmful or distasteful one, as viceroy butterfly to monarch.

Protein (Gk. *protos*, first): a compound of oxygen, hydrogen, carbon, and nitrogen, with traces of other elements; a component of protoplasm; a nutrient.

Protho'rax (Gk. *pro*, before, + *thorax*, chest): the first of the three regions of an insect's thorax.

Pro'toplasm (Gk. *protos*, first, + *plasma*, molded form): the living substance composing the cells of plants and organisms.

Protozo'a (Gk. *protos*, first, + zoön, *animal*): one-celled animals.

Pseudopod'ium (Gk. *pseudes*, false, + *pous*, foot): a projection of protoplasm used by protozoöns for locomotion.

Pto'maine (Gk. *ptoma*, corpse): a poisonous substance produced by the decomposition of animal matter.

Pty'alin (Gk. *ptyalon*, spittle): the enzyme in saliva which changes starch to sugar.

Pulse (Lat. *pulsus*, beating): the beating of the blood vessels near the surface, as at the wrist.

Pupa (Lat. *pupa*, puppet): the quiescent, inactive stage in the development of an insect between larva and adult.

Pupil of the eye: the round opening in the iris which admits light into the eye.

Pylor'us (Gk. *pylorōs*, gate-keeper): the opening between the stomach and the intestine.

Q

Quar'antine: the enforced isolation of persons or places infected with contagious diseases.

Quarter-sawn timber: that which is sawed lengthwise into quarters to show the medullary (wood) rays obliquely, especially *quartered oak*.

QUEEN BEE: the mother of a community of bees whose only duty is to lay eggs in cells prepared by the workers; a perfect female bee.

R

RACEME' (Lat. *racemus*, cluster): a form of inflorescence in which the flowers are arranged spirally around a central axis, as lily-of-the-valley.

RĀ'PHE (Gk. *raphē*, a seam or suture): the band running lengthwise around the outside of a bean seed.

RAPTO'RES (Lat. *rapere*, to ravish): an order of birds having sharp, hooked beaks and strong, sharp talons; birds of prey.

RAY FLOWERS: the outer flowers of certain composite "flowers," for example, common daisy, with white ray flowers, sunflower, with yellow ones.

RECEP'TACLE (Lat. *re*, back, + *capio*, take): the expanded end of a modified branch on which the floral parts are arranged.

RECES'SIVE (Lat. *re*, back, + *cedo*, yield) CHARACTERS: those which do not appear in a hybrid, owing to the dominance of other characters.

RE'CLAMATION (Lat. *re*, again, + *clamo*, call): the act of bringing wild or arid land to use in raising crops; supplying water for irrigation.

REC'TUM (Lat. *rectus*, straight): the terminal portion of the alimentary canal.

RED RUST: a parasitic fungus which has two hosts, wheat and barberry, during its life history; called also black rust from its mature stage on wheat.

RE'FLEX (Lat. *re*, back, + *flecto*, bend) ACTION: that which takes place in voluntary muscles without the intervention of the mind, the stimulus going first to the spinal cord and being switched to the motor nerves, causing movement.

RE'FORESTA'TION: the act of replanting areas with trees, or setting out trees on new areas.

RE'GENERA'TION (Lat. *re*, again, + *genero*, beget): the act of restoring a lost part by growing a new one, as the tentacle of a hydra, or the end of an earthworm.

REGULAR FLOWER: one which has all its petals, also its sepals, the same size and shape, as rose, buttercup. Pansies, violets, and salvia have *irregular* flowers.

REPEL'LENT (Lat. *re*, back, + *pello*, drive): a substance which makes plants distasteful to their insect enemies.

REPRODUC'TION (Lat. *re*, again, + *pro*, before, + *duco*, lead): the act of bringing forth another thing of the same kind; generation.

RESPIRA'TION (Lat. *re*, again, + *spiro*, breathe): the life function which consists of getting and using oxygen for oxidizing protoplasm to release energy, and removing the carbon dioxide resulting from oxidation.

RET'INA (Lat. *rete*, net): the inmost layer of the coat of the eyeball which receives the stimuli of light rays and conducts them to the brain through the optic nerve.

RHI'ZOME (Gk. *rhiza*, root): a thickened, underground stem used for food storage, as in Solomon's seal and pteris, or for propagation, as in quack grass and Canada thistle.

RODEN'TIA (Lat. *rodo*, gnaw): a group of animals having chisel-edged incisor teeth for gnawing, as squirrel, rat.

ROOT CAP: the loose protective cells covering the end of a rootlet.

ROOT HAIRS: elongated projections of epidermal cells of roots for absorption.

ROOT PRESSURE: the osmotic force which causes sap to rise in stems.

ROSETTE' (Lat. dim. of *rosa*, rose): the spiral arrangement of leaves on a very short axis, as shepherd's purse or bull thistle in early spring.

RU'MINANT (Lat. *rumen*, throat): an animal which chews its cud, as cow. The food is swallowed with very little chewing while eating. Later it is returned to the mouth partially digested and is thoroughly chewed.

RUST: a form of plant disease caused by certain fungi; especially red rust (black rust) of wheat.

S

SALI'VA (Lat. *saliva*, spittle): the natural moisture in the mouth secreted by the salivary glands.

SAMA'RA (Lat. *samara*, elmseed): an indehiscent winged fruit, as in maple, elm, and ash.

SANC'TUARY (Lat. *sanctio*, make holy): a place of refuge from violence, particularly designated localities where birds or other animals may not be molested.

SANITA'TION (Lat. *sanitas*, from *sanus*, whole): the devising and applying of measures for preserving and promoting health, especially public health.

SAN JOSÉ SCALE: an injurious insect which infests fruit trees.

SAP: the liquids which circulate in plants.

SAP'ROPHYTE (Gk. *sapros*, rotten, + *phyton*, plant): the group of fungi which live on dead organic matter.

SCAP'ULA (Lat. *scapulae*, shoulder-blades): one of the shoulder-blades.

Sci'on (Lat. *seco*, cut): the small branch inserted into the large plant (stock) in grafting.

Sclerot'ic (Gk. *sklēros*, hard) coat: the tough outer coat of the eyeball.

Scute (Lat. *scutum*, scale): one of the large scales on the abdomen of a snake.

Scutel'lum (Lat. dim. of *scutum*, shield): the shield-shaped cotyledon lying under the embryo in corn and other grains.

Secre'tion (Lat. *se*, aside, + *cerno*, separate): a substance separated or elaborated from blood or sap; the act of forming such a substance.

Seedling: a young plant during the period when it is dependent on food stored in the seed.

Seg'ment (Lat. *segmentum*, from *seco*, cut): one of the ring-like divisions of the abdomen of insects, and of earthworm.

Self-pollination: the act of getting pollen on the pistil of any flower from its own stamens.

Sensa'tion (Lat. *sensatus*, from *sentio*, feel): the consciousness (awareness) of a stimulus received through a sense organ.

Sen'sory (Lat. *sentio*, feel) nerves: those which convey stimuli *to* the brain, producing sensation.

Sex'ual (Lat. *sexus*, sex) reproduc'tion: that in which the new individual arises from the union of an egg and a sperm.

Sieve cells: large cells with perforated ends which are a part of the phloem of a fibrovascular bundle.

Simple eye: a single organ of sight found in insects, resembling one of the numerous parts of the compound eyes.

Sinus (Lat. *sinus*, bend): a hollow or cavity in a bone; an irregular, widened space in a vessel or among the cells of a tissue.

Si'phon (Gk. *sipho*, siphon): one of the openings in the mantle of a clam through which water flows in or out.

Siphun'cula'ta (Gk. dim. of *sipho*, siphon): an order of insects which have sucking mouths, as sucking lice.

Skel'eton (Gk. *skeleton*, dried body): the firm part of an animal's body to which the muscles are attached.

Skin: the outer covering of an animal's body.

Soil (Lat. *solum*, bottom): the finely divided particles of rock, humus, etc., which make up the outer layers of the earth not covered by water.

Sol'id (Lat. *solidus*, dense): a form of matter neither gaseous or liquid, as wood, stone, clay.

Sol'itary (Lat. *solitarius*, solitary): single; alone; especially a flower which grows at the end of its own stalk.

Sol'vent (Lat. *solvo*, set free): a fluid which makes other substances fluid also.

Spawn: to deposit eggs or roe for reproduction, as fishes.

Spec'ial senses: seeing, hearing, smelling, tasting, feeling.

Sperm (Gk. *sperma*, from *speiro*, sow): the male element in sexual reproduction.

Sperm'ary (Gk. *sperma*, from *speiro*, sow): the organ which produces sperms; the testis.

Spic'ule (Lat. *spiculum*, dim. of *spicum*, point, spike): a small, hard, pointed body found in sponges.

Spinal nerves: those arising from the spinal cord, a pair from each vertebra.

Spir'acle (Lat. *spiraculum*, air-hole): an opening for air in the body of an insect or whale.

Spiril'lum (Gk. *speira*, coil, wreath): a spiral form of bacterium.

Spleen (Gk. *splēn*, spleen): a ductless organ lying in the abdominal cavity.

Sporan'gium (Gk. *spora*, a seed, + *angeion*, a receptacle): the case in which spores are produced.

Spore (Gk. *spora*, a seed): a non-sexual reproductive body common to fungi, mosses, and other plants.

Sprain: the injury resulting from a violent twisting or pulling of the ligaments.

Spur: a short, stiff, sharp spine, as on a rooster's leg.

Spu'tum (Lat. *sputus*, from *spuo*, spit): expectorated matter characteristic of certain diseases.

Sta'men (Lat. *sto*, stand): the organ in a flower which produces pollen.

Starch: a substance composed of carbon, hydrogen, and oxygen, hydrogen and oxygen occurring in the same proportion as in water; a carbohydrate.

Steapsin: a digestive ferment found in the pancreatic juice and assisting in the digestion of fats.

Stegomy'ia: the species of mosquito which is the host of the malarial parasite during one phase of its life history, transmitting it to man by its bite.

Ster'ile (Lat. *sterilis*, barren): free from bacteria of every kind.

Ster'num (Gk. *sternon*, breast): the breast bone.

Stig'ma (Gk. *stigma* from *stizō*, prick): the part of a pistil which receives the pollen.

Stim'ulant (Lat. *stimulus*, goad): any agent that excites to organic action.

STIM'ULUS (Lat. *stimulus*, goad): that which causes a reaction in nerve, muscle, or vegetable tissue, as light, sound, electricity, warmth, etc.

STING: an organ of offense or defense in animals, as bees, wasps, etc.; hollow hairs of plants filled with acrid liquid secreted by the plant, as nettle.

STIP'ULE (Lat. *stipula*, stalk): one of the two leaf-like growths at the base of the petioles of certain leaves, as clover, strawberry.

STOCK: the large stem on to which a smaller one (scion) is grafted.

STO'LON (Lat. *stolo*, twig): a thread-like, leafless branch which has a vegetative bud on the end, as in strawberry.

STO'MA (Gk. *stoma*, mouth): one of the very small openings in the epidermis of a leaf through which water vapor passes out and air in.

STOM'ACH (Gk. *stomachos*, from *stoma*, mouth): the sac or enlarged portion of the digestive tract in which digestion is carried on.

STRAP-SHAPED FLOWER: one in which the narrow petals are united and turned in the same direction, as in dandelion.

STYLE (Gk. *stylos*, pillar): the slender portion of a pistil connecting the stigma and the ovary.

SUCTO'RIA (Lat. *suctus*, from *sugo*, suck): an order of insects which have sucking mouths, as fleas.

SUF'FOCATE (Lat. *suffocatus*, from *suffoco*, choke): to kill by excluding air from the lungs or by substituting some other gas for air, as smoke.

SUG'AR: a carbohydrate of sweetish taste, soluble in water. (See *starch*.)

SUL'PHUR: one of the elements found in protein. It forms a combination with hydrogen in decomposing protein which is ill-smelling.

SU'TURE (Lat. *sutura*, from *suo*, sew): the joining of two bones by mutually serrated edges, forming an immovable articulation, as in the bones of the skull.

SWARM'ING: the departure from the hive of a queen bee and most of the workers.

SWIMMERETS': small appendages on the abdomen of a crayfish, useful in swimming.

SYMBIO'SIS (Gk. *syn*, together, + *bios*, life): the close relationship of two organisms which results in mutual benefit.

SYS'TEM (Gk. *syn*, together, + *histēmi*, stand): a group of organs which work together to perform a life function, as digestive system, circulatory system.

T

TACHI'NA-FLY: a useful dipterous insect which lays its eggs on the larvae of potato beetles.

TAD'POLE: the larval stage of frogs and toads.

TAL'ON (Lat. *talus*, heel): a claw, especially of a bird of prey.

TAR'SUS (Gk. *tarsos*, any flat surface): the ankle; the scaly part of a bird's leg; the terminal segment of an insect's foot.

TEN'DON (Lat. *tendo*, stretch): the connective tissue ending of a muscle which attaches it to other structures.

TEN'DRIL: an organ of certain plants which clasps a support, enabling it to climb.

TEN'TACLE (Lat. *tento*, touch, try): a jointed flexible appendage on the head of insects and other invertebrates, used for touch, grasping, or motion; a feeler.

TER'MINAL (Lat. *terminus*, boundary) BUD: one which appears at the end of a branch or stem.

TER'RAPIN: one of the tortoises or land turtles.

TES'TA (Lat. *testa*, shell): the hard outer covering of a seed.

TES'TIS (Lat. *testis*, a testicle): an organ in a male animal where sperms are produced.

THALES'SA: a useful ichneumon fly which destroys the larvae of Tremex, a wood borer.

THORAC'IC (Gk. *thōrax*, thorax) CAVITY: the second part of an insect's body; in mammals, the cavity above the diaphragm; the chest cavity.

THY'ROID (Gk. *thyreos*, large shield) GLAND: a large ductless gland on the outside of the trachea below the larynx.

THYSANU'RA (Gk. *thysanos*, fringe, + *oura*, tail): an order of insects having bristles on the end of the abdomen, as in fish-moths.

TIB'IA: the shin bone in man; the fourth division of an insect's leg.

TIS'SUE (Lat. *texo*, weave): a collection of similar cells that perform the same function.

TON'SIL (Lat. *tonsilla*, tonsil): one of two ductless glands lying in the throat back of the tongue.

TOX'IN (Lat. *toxicum*, poison): a poisonous substance given off by disease-producing bacteria.

TRA'CHEA (Gk. *tracheia*, windpipe): the air passage leading from the pharynx to the lungs; an air tube in insects.

TRANSPIRA'TION (Lat. *trans*, through, + *spiro*, breathe): the evaporation of water through the stomata of leaves.

TREE SURGERY: the scientific treatment of diseased trees, consisting of pruning, filling cavities, and so on.

TRICHINEL'LA (Gk. *thrix*, hair): a small round worm sometimes found in pork living as a parasite, and the cause of trichinosis in man.

TRI'CHOCYSTS (Gk. *thrix*, hair, + *kystis*, bag): minute, dart-like organs of offense and defense found in paramecium.

TRICHOP'TERA (Gk. *trichos*, gen. of *thrix*, hair, + *pteron*, wings): a group of insects having long, hair-like projections from the end of the abdomen.

TRO'CHANTER (Gk. *trochantēr*, from *trechō*, run): the second joint of an insect's leg.

TRUNK: the stem of a tree; the main part of the body of a vertebrate to which the appendages are attached.

TRYP'SIN (Gk. *tripsis*, a rubbing): a digestive ferment, found in pancreatic juice and acting on protein substances.

TU'BER (Lat. *tuber*, a swelling): a short, thick underground stem used for storage, as potato.

TUR'GID (Lat. *turgeo*, swell): distended with air or liquid; swollen.

TYMPAN'IC (Gk. *tympanon*, drum) MEMBRANE: the thin partition which separates the middle ear from the outer, commonly known as the ear-drum.

U

UNGULA'TA (Lat. *unguis*, nail): a group of mammals characterized by hoofs.

U'REA (Lat. *urina*, urine): the nitrogenous waste of animals which is passed off in the urine.

URE'TER (Gk. *ourētēr*, from *ouron*, urine): a tube, one of two, leading from the kidneys to the bladder and carrying off the nitrogenous waste in the urine.

U'RINO-GEN'ITALS (Lat. *urina*, urine, + *genitalis*, from *gigno*, beget): the organs common to the urinary and the reproductive systems, or the combination of these systems.

U'ROPOD (Gk. *oura*, tail, + *pod*, from *pous*, foot): the modified swimmeret on either side of the last segment of a crayfish. These, together with the telson (the modified last segment) make up an appendage useful in swimming backwards.

V

VACCINA'TION (Lat. *vacca*, cow): inoculation with the virus of cowpox as a preventive of smallpox. The term is loosely used to denote inoculation for other diseases.

VACCINE' (Lat. *vacca*, a cow): the virus of cowpox prepared for or introduced by vaccination.

VAC'UOLE (Lat. *vacuus*, empty): a space in the protoplasm of a cell

usually filled with a clear liquid secreted by the cell, or by food in the process of digestion.

VALVE (Lat. *valva*, leaf of a door): one or more folds in the lining tissue of a blood vessel or other organ to prevent or check the flow of a liquid in the opposite direction.

VARIATION (Lat. *varius*, various): deviation from the type in structure or function.

VAS'CULAR (same as fibrovascular) BUNDLES (Lat. *vasculum*, a little vessel): elongated cells which communicate with each other, forming tube-like vessels for the transportation of liquids in plants.

VEIN: (Lat. *vena*, blood vessel): one of the vessels which conducts blood towards the heart; one of the ribs of an insect's wing; one of the larger supporting and conducting vessels in a leaf.

VEL'AMEN (Lat. *velare*, to veil): a pendant air root of certain orchids adapted to gather and store moisture.

VEN'TRAL (Lat. *venter*, belly): pertaining to or situated on the abdominal side of the body.

VEN'TRICLE (Lat. *ventriculus*, a little belly): any cavity of a hollow organ, especially one of the lower chambers of the heart.

VERMI'FORM (Lat. *vermis*, worm, + *forma*, form) APPEN'DIX (Lat. *ad*, to, + *pendo*, hang): a slender tubular pouch of the large intestine near its juncture with the small intestine.

VER'TEBRATES (Lat. *verto*, turn): the group of animals which have backbones.

VIABIL'ITY (Lat. *vivo*, live): having life or the ability to live, as a seed.

VILLI (Lat. *villus*, a hair): the minute projections which cover the lining of the small intestine; an organ of absorption.

VI'RUS (Lat. *virus*, poison): the element or principle that is the agent or medium for communicating infection.

VIS'CERA (Lat. *viscus*, an organ of a cavity of the body): the organs of the abdominal cavity.

VI'TAMIN (Lat. *vita*, life): certain substances in foods which are necessary for the proper functioning of the vital processes.

VITREOUS (Lat. *vitrum*, glass): the liquid which fills the posterior chamber of the eyeball.

VIVIP'AROUS (Lat. *vivo*, live, + *pario*, bear): producing young alive, as cat, man.

VOLUNTARY (Lat. *voluntas*, will) MUSCLES: those under the control of the will, as the hand.

VOLVOX: a colonial organism in which the individual cells show the division of labor.

W

WARM-BLOODED: having a constant temperature, as man.

WARNING COLORATION: marks or colors which make an insect or other animal conspicuous to its enemies.

WEED: a plant that grows where it is not wanted.

WIG'GLER: the larva of mosquitoes.

WORKERS: underdeveloped females in a community of bees which perform all the work of the hive except reproduction.

WORM: a group of animals having flat or cylindrical bodies which in some cases are composed of segments.

X

XY'LEM (Gk. *xylon*, wood): the thick-walled cells in a fibrovascular bundle.

Y

YEAST: a unicellular fungus which causes fermentation.

YOLK: the yellow portion of an egg; the food material used by the embryo.

Z

ZY'MASE (Gk. *zymē*, a ferment): the ferment or enzyme found in yeast.

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Biology is the
study of living plants
and animals.
Louis Pasteur discovered
that no spontaneous origin
of life took place when
the germs were excluded.

Irma Compton
Stuart Chisholm

Irma Compton
Gold Hill, Oregon.

Ruth Cameron
Clyde Kell

Ruth Cameron